ROSENAU

A PRACTICAL GUIDE TO DISINFECTION

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A PRACTICAL
GUIDE TO DISINFECTION

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BY

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With a Supplement

BY

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TO

THE MEMORY OF

THE

OFFICERS OF THE U. S. MARINE-HOSPITAL SERVICE

WHO HAVE LAID DOWN THEIR LIVES

FIGHTING INFECTION

IN ORDER TO PROTECT THEIR

FELLOW-MEN

PREFACE.

I have made mistakes, and I have seen others make similar mistakes in learning what, how, and when to disinfect. This book has been written with the hope that it may help others who have to battle with the infection of the communicable diseases.

I have tried to set down the results of my experience gained in sanitary work of a public health character, both in the field and in the laboratory. The many recent text-books upon bacteriology, hygiene, and sanitary science have been freely consulted.

It has been my aim to state the important facts tersely and in a form to be of practical use to the disinfector. Controversies have been avoided, even at the risk of being dogmatic, and upon doubtful points the safer methods have always been given the preference.

The subject has been considered from the standpoint of the disinfectant used, the object to be disinfected, and the disease for which the disinfection is done. In considering any subject from three points of view a certain amount of repetition is unavoidable.

It is a pleasure to acknowledge the debt I owe to Surgeon-General Walter Wyman, whose aid and encouragement have made this work possible.

These pages have been a work of love, and I trust that they may prove a useful and trustworthy guide.

September, 1902.

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DISINFECTION AND DISINFECTANTS.

INTRODUCTION.

Disinfection is the destruction of the agents causing infection.

An object is said to be infected when contaminated with the living principles—that is, the micro-organisms—causing disease. It is disinfected by destroying these organisms, whether they are in the substance or on the surface of that object.

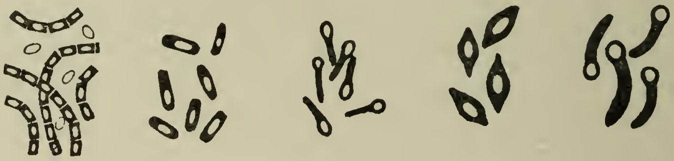
As a matter of fact it is not necessary actually to destroy the infective agents; it is sufficient to render them incapable of causing or conveying disease. For example, if the micro-organisms are so attenuated that they have lost their virulence, or if they are so scattered that they are too few to cause infection, the object of disinfection has been accomplished.

Of course, dilution, attenuation, and the like fortuitous circumstances cannot be depended upon by the disinfector. He must use means that will surely destroy the infectious principles. The only way an infected object may with certainty be rendered safe from the danger of conveying disease is by the intelligent application of physical means or chemical substances which experiment and experience have shown will invariably destroy the infection.

The ideal disinfectant is one that destroys the germs without injury to the object. There is no one agent or method applicable to all cases; it is therefore necessary to determine accurately all the conditions, not only of the object to be disinfected, but of the germicide to be used, and to take into account the resistance of the particular morbific principle against which the disinfection is directed.

Disinfection, then, deals only with destroying the vitality of those minute forms of life which cause disease; it does not mean the destruction of all the lower forms of animal and vegetable life that may be upon or in an object—that is sterilization.

FIG. 1.



BACTERIA WITH SPORES.—(*Williams.*)

An object is said to be sterilized when all the forms of life contained within it or on its surface are destroyed. All processes which sterilize are necessarily also disinfectants; but all disinfecting processes by no means cause sterilization.

This distinction between disinfection and sterilization arises principally from the fact that some of the micro-organisms have spores, which correspond to the seeds of plants, in being very much more resistant to all the influences which destroy the parent cells. Spores of this character, called endogenous spores, possess to a very high degree the power of resisting desiccation, sunlight, chemical and physical agents which quickly destroy the non-spore-bearing cell. Fortunately, as far as known, none of the pestilential diseases of man, which occur in widespread epidemics, is caused by organisms with resistant spores. Therefore, the usual processes of disinfection, while thoroughly efficient, may still leave many harmless and hardy bacteria alive. In other words, sterilization is rarely necessary in combating epidemic diseases.

Antiseptic substances prevent decomposition and decay. Such substances retard the growth and activity of the micro-organisms, but do not destroy them. There is a great difference between the antiseptic and the disinfecting or germicidal value of a substance. For instance, a solution of formalin will restrain the development of most bacteria in the proportion of 1 to 50,000, but it requires a 3 to 5 per cent. strength of this substance to kill the bacteria in a short time. As weak a solution of bichlorid of mercury as 1 : 300,000 will restrain the development of anthrax spores, whereas it requires a 1 : 1000 solution to destroy them. Saturated solutions of salt or sugar will preserve meat or vegetable substances; that is, they are antiseptic in their action, but not germicidal, as they have small powers of destroying infection.

The condition known as asepsis is equivalent to sterilization. Asepsis means the freedom from or the absence of pathogenic micro-organisms.

A germicide is a substance or agent which destroys germs. Germicides and disinfectants are interchangeable terms, as they are both used to indicate the destruction of micro-organisms.

A substance which has the power to destroy or to neutralize the unpleasant odors arising from organic matter undergoing fermentation or decomposition is called a deodorant. Such substances must be carefully distinguished from disinfectants. Deodorants destroy smells, disinfectants destroy germs. A majority of the disinfecting agents are also deodorants, but all the deodorizing substances are by no means disinfectants. For example, charcoal will absorb the malodorous gases arising from putrefying and fermenting materials, but it is inert so far as its power to destroy the cause of these processes is concerned. Formalin, on the other hand, is a true deodorant and disinfectant, as it combines with the organic matter to form new compounds which are both odorless and sterile. Bichlorid of mercury, while a very potent germicide, has but slight immediate effect upon odors.

In nature, many forces are constantly at work to destroy infection and thereby limit the spread of the communicable diseases. We should make use of these natural disinfecting agencies by placing objects under the most favorable circumstances for them to exert their maximum effect.

These natural influences are chiefly dilution, light, dryness, symbiosis, and heat. Of these agencies, sunlight is the great destroyer of germ life. Few microbes, especially the pathogenic ones, can live in the direct, bright sunlight many hours. Dryness is another condition that is destructive to many of the forms of life with which we have to deal. The combination of dryness and sunlight is almost as good as the gaseous disinfecting processes which are commonly used in actual house disinfection against surface contamination. Dryness, sunlight and cleanliness are the keynotes of sanitary surroundings in the modern acceptation of the term.

Cleanliness is an important adjunct to the work of disinfection. The mere act of cleaning removes some of the adherent microbes from the surface, and the ordinary scrubbing and mopping results in the final destruction of many more. Dry dusting and sweeping only serve to stir up the dust and infection, which disseminate in the air to settle down again upon the same or other surfaces.

Cleanliness accomplishes another important purpose as far as infection is concerned: It removes the organic matter on which and in which the bacteria find favorable conditions for prolonging life and virulence.

In the wholesale disinfection which must be practised to check widespread epidemic diseases due to bacterial infection we are largely limited to the use of the agents which nature has constantly at work to destroy such infection. Against a single case of communicable disease, or against a limited infected area, we may employ aggressive measures, such as steam and strong chemicals; but when a disease due to bacterial infection has spread over an extensive district, these methods must be supplemented by all the resources of nature. The people must be in prime health to resist the disease. Cleanliness must be more scrupulously practised than ever in order that organic filth may not be present to afford a favorable soil for the life, growth and dissemination of the infective agents. Sunlight and dryness must be given their fullest opportunity to operate, even at the expense of a few faded carpets or colors.

Many of the pathogenic micro-organisms are destroyed by the processes of putrefaction and fermentation of organic matter. They die in the fierce struggle for existence going on in these destructive processes. For the most part, the hardier saprophytic forms of life overpower and kill the disease-producing microbes, which have comparatively feeble powers of resistance. The fact that infected carcasses, sewage and putrid organic matter largely purify themselves by the very processes that destroy them is a fortunate provision of nature.

With the advent and advance of the science of bacteriology the practice of disinfection was directed against the destruction of bacteria wherever they were found—in the air, the soil, the water, on clothing and fabrics, or about the patient and his discharges. But with the advance in our knowledge of disease, and especially with the knowledge that disease germs are frequently conveyed from the sick to the well through the agency of other animals, disinfection has come to include the destruction of vermin and insect pests. In disinfecting for malaria, yellow fever and filariasis, we must destroy the mosquitos which convey the infection. In disinfecting for cholera, typhoid fever and other diseases, we must pay attention to the flies and other winged insects which have been in contact with the infected discharges. In the disinfection for plague, we must destroy the infected rats, mice and fleas.

In fact, as our knowledge of the subject increases we find that domestic animals and vermin are playing a very conspicuous rôle in the transmission of disease. So dangerous do we now know that the fly and mosquito may be, that when the matter is more generally understood it should be a greater reproach to the housewife to have these dangerous vermin in the household than to have bedbugs.

It naturally suggests itself that it is much better to prevent infection than to be compelled to destroy it after it has become disseminated through ignorance, carelessness or negligence.

It is the duty of the disinfector to destroy infection wherever it is found. It is the duty of the sanitarian to prevent and avoid infection. For instance, in the case of cholera the sanitarian protects the water-supply, but if it becomes contaminated the disinfector must know how to render it safe. In the case of diseases due to animal parasites and conveyed by insects, the disinfector must know how to destroy the infected insects. It is the sanitarian's province to institute measures looking to the extermination of the insects or to the protection of the individuals against their bites.

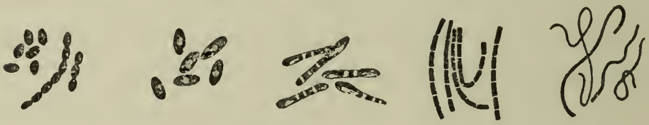
The best way to apply disinfection is at the seat of origin of the infection. This means the inunction of the skin in the case of the exanthemata; the destruction of the specific poisons in the stools and urine of typhoid fever, cholera and dysentery; the boiling or burning of the sputum of tuberculous patients; and strict measures applied to each case which will prevent the dissemination of the pathogenic germs from the body in live and virulent form.

When proper precautionary measures have been taken at the bedside with a case of cholera, typhoid fever, plague, or the like infectious diseases, there is little need of subsequently disinfecting the sick-room. But when due to carelessness or lack of precaution, the result of ignorance, a general diffusion of the infection results, then a general disinfection becomes necessary. It is the province of the disinfector to know how best to deal with such conditions, so as to render them harmless.

The disinfection of any given place is a complex operation, and should not be attempted by any one not familiar with the peculiarities of the particular infection with which he has to deal, and not possessing a thorough knowledge of the disinfecting agents employed. Fortunately, most of the germs which cause the communicable diseases in man are non-spore-bearing micro-organisms. They are therefore comparatively easy to eradicate by disinfection. Spores possess very great resisting powers against all our disinfecting agents, and are much more difficult to kill than the micro-organisms themselves. For example, almost all bacteria may be killed by drying alone, by which, generally speaking, spores are little influenced.

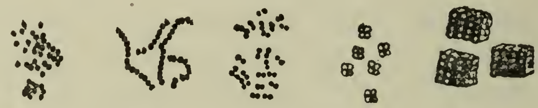
As a rule the bacilli are less resistant than micrococci, and the vibrios are less resistant than either the bacilli or the micrococci. Individual bacteria from the same culture vary in their vitality, just as one member of a family is stronger than another. Geppert* has shown that spores from the same spore-bearing bacillus have very different powers of resistance. This fact has a practical bearing in drawing conclusions from laboratory experiments as to the effect and value of germicidal agents in actual practice. It also explains, in part, the discrepancies as to the times of exposure and the strengths of solutions necessary to accomplish disinfection, as stated by different experimenters.

FIG. 2.



BACILLI OF VARIOUS FORMS.—(*Williams.*)

FIG. 3.



Staphylococci. Streptococci. Diplococci. Tetrads. Sarcinae.

THE VARIOUS ARRANGEMENTS OF MICROCOCCI.—(*Williams.*)

The communicable diseases are by no means all due to bacteria. A very large and important class of these affections is due to animal parasites.

Bacteria are the lowest forms of vegetable life. They are minute microscopic cells, very variable in shape. Round ones are called cocci; those shaped like a rod, bacilli; and the curved and corkscrew-shaped ones are called vibrios or spirilla. Many of them have independent motion. All bacteria multiply by a simple process of division or fission. Some of them have spores. They all require moisture for their development, and grow best upon organic substances. For a full account of bacteria and their products it will be necessary to refer to one of the many excellent works upon this subject.

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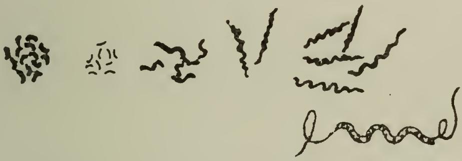
* "Berliner klin. Wochenschrift," 1889, No. 36, p. 791; also 1890, No. 12, p. 27.

Many kinds of animal parasites cause disease in man. By far the most important is the group of protozoa, which resemble the bacteria only in being minute microscopic cells with independent motion. In other respects they have all the functions of animal life. They multiply both by direct division, similar to the asexual fission of bacteria, and by a sexual union. Some of the animal parasites have spores, but not of the same high degree of resistance as the endogenous spores of bacteria. The animal parasites of man are usually communicated from the sick to the well through an intermediate host.

FIG. 4.



SPIRILLA OF VARIOUS FORMS.—(*Williams.*)

A distinction is often drawn between the "contagious" and the "infectious" diseases. These terms have always lacked scientific precision, and have been the source of some confusion. The word "communicable" is a much better term for all the diseases of this class, and has been given the preference in this work.

In the old acceptation of the word, a contagious disease was one that was "catching" by contact between the sick and the well. It was believed that the contagion was thrown off in the exhaled breath and contaminated the atmosphere surrounding the patient. With the possible exception of smallpox, and typhus fever when it prevails in epidemic form, there are few contagious diseases according to this meaning of the term.

An infectious disease, on the other hand, is one spread from the sick to the well in an indirect manner. The infective agent contaminates the water, food-supply, or other object, through which means the disease is communicated to well persons who in no way come in contact with the sick.

These distinctions are entirely artificial and serve no useful purpose. Almost every one of the communicable diseases may be transmitted from the sick to the sound in a great variety of ways. In the light of our present knowledge it is not practicable to classify this group of diseases according to their methods of propagation, and it is therefore preferable to speak of them under one heading.

In the body the immunity or resistance to disease is an active protection to the individual, and may act as a check to the spread of infection; on the other hand, such individuals often spread the contagion of pestilential affections. Almost every one of the great epidemic diseases may present itself in so mild or latent a form that neither the individual nor his associates suspect that in his system he is harboring the infective principles and spreading the contagion to others. For instance, many persons have the bacillus of diphtheria in their mouths without suffering any local or general symptoms. Such persons may spread this infectious disease by kissing, by using cups, spoons, etc., which are shortly thereafter placed in the mouths of others more susceptible to this micro-organism and who thereby contract a severe or fatal type of diphtheria. Similarly, many persons have tuberculosis a long time before they suspect it, and may spread it in a similar manner. There are cases of cholera so mild that it cannot be recognized except by bacteriologic examination; in truth, the virulent, live cholera vibrio may exist in great numbers in the intestinal canals of apparently healthy individuals. The dejecta from such a person might unwittingly be permitted to contaminate the water-supply of a large city, resulting in a serious epidemic.

It is well known that yellow fever may occur in very mild form,—very difficult to recognize,—and it is doubtless just such cases that are the spark to kindle an epidemic. As clearly defined a disease as smallpox may be so mild that the patient has only a few pustules, with very slight constitutional disturbances. Walking cases of typhoid fever are not uncommon. Such cases are difficult to recognize. The same may be said of practically all the known communicable diseases.

The belief is growing stronger that the communicable diseases are more often spread through the intermediation of these mild, latent and unrecognized cases than through the agency of fomites—that is, inanimate objects. It has long been well known that disease may be communicated from the sick to the well by a third person, and it was formerly supposed that this was always the result of the infection clinging to the clothing, hair, etc., of the person; but we now know that it may also be due to the infection growing in the body of the individual. Diphtheria is a well-known instance of the conveyance of infection by both of these methods. The diphtheria bacillus may be growing in the secretions of the throat of the individual, or may remain alive and virulent attached to his clothing or to some other object about his person.

When disease recurs in a house, we must not be too quick to blame the disinfector or the methods used by him, for frequently the infection lurks on the persons of the inmates of the house, rather than in the furnishings and contents of the rooms.

We know the part played by inanimate things in the transmission of some of the communicable diseases, but as our knowledge of the subject increases, their importance diminishes. As Dr. J. H. White tersely expresses it, ''Infection is more often conveyed from place to place in a pair of shoes than on the clothing or in the baggage of the person.''

The disinfector must therefore know the best methods of purifying rooms, theaters, cars, meeting-places, schools, barracks and other places where many persons assemble and where latent, mild, or unrecognized cases are constantly suspected or are actually occurring to contaminate the surroundings.

There is no accurate standard by which the power of disinfecting agents may be measured. There are conditions influencing the life of the bacterial cell which we are unable to control. It is for this reason that the strengths of solutions necessary to disinfect are variously stated by different authorities, and the time of exposure is, for the same reason, not always definitely decided. The difficulty in this connection is to determine the minimum conditions which will furnish trustworthy results and still provide that excess necessary for general practice, or what bridge-builders call the ''coefficient of safety.''

While the results of the scientific work in the laboratory must be our guide as to the value and efficiency of any disinfecting process, we cannot ignore the results of experience gained in actual practice in combating the communicable diseases. This is especially true of disinfectants used against diseases the cause of which is only surmised, or the mode of transmission not definitely known. We have recently had a lesson on this point in the case of sulphur. This substance had long been used as a disinfectant for yellow fever, and practical experience had justified the confidence placed in sulphur fumigation to check the spread of this disease. But when the scientific tests made in the laboratory showed that sulphur dioxid lacks the power of destroying resisting spores, great discredit was thrown upon it. But now we know that yellow fever is transmitted through the agency of the mosquito, and with the well-known insecticidal powers of sulphur dioxid confidence has been restored both as to the scientific and the practical value of this substance.

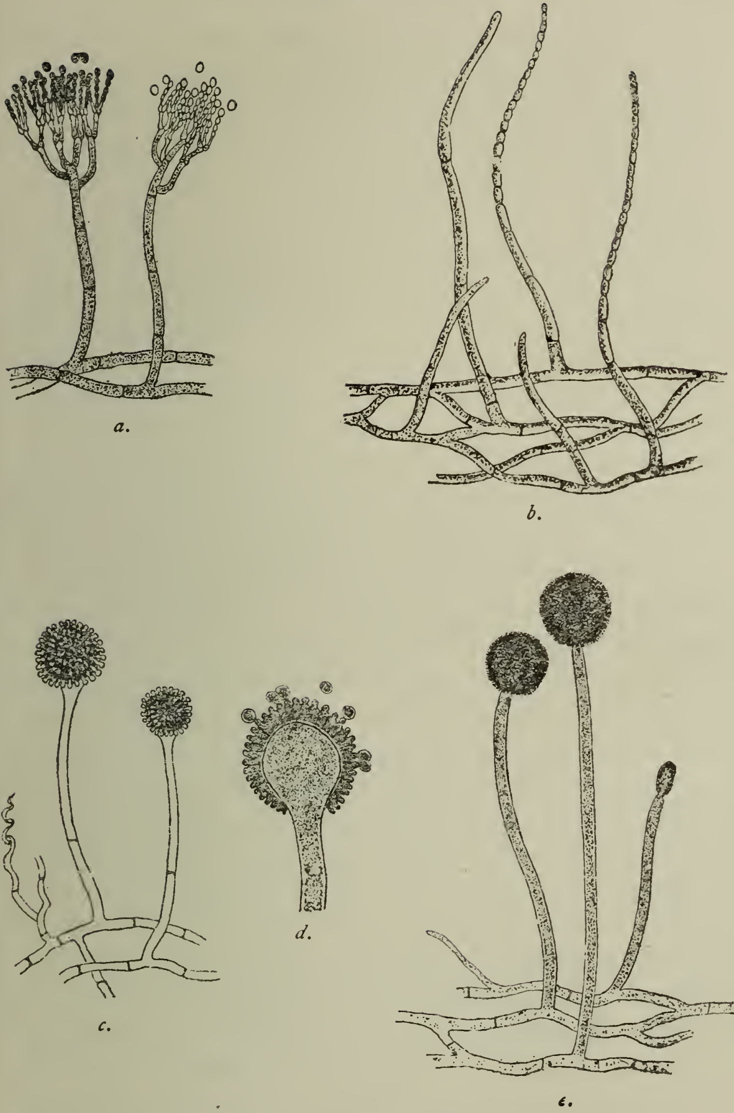
On the other hand, laboratory experiments have established with great accuracy the value and reliability of certain substances which otherwise would have gone begging. Some substances, such as zinc chlorid and sulphate of iron, have been robbed of the high value in which they were formerly held, and placed near the bottom of the list of disinfectants. Even carbolic acid, which at one time was so highly prized, has been shown to have less germicidal power than was supposed.

The success of the disinfector lies in personal attention to the minute details. Germs are little things, and it is the little things that count in this kind of work. The disinfector who is satisfied to leave the process in the hands of an inexperienced person, with a few words of instruction, cannot expect to obtain trustworthy results. In no other work is the watchword that "vigilance is the price of success" truer. The disinfector must give personal surveillance to the whole process—the materials, the strength of solutions, modes of application—and must be present to guide and direct every step of the operation, with the same conscientiousness and thoroughness with which the surgeon assures himself of every detail of asepsis in his operating room.

It is true that the means and methods employed to rid a room of infection closely resemble those used in the operating room, but it stands to reason that in the former case they can rarely be carried out with the same exactness and certainty as in the latter, where everything is constructed and arranged with this end in view. In the surgical clinic nothing short of sterilization is safe, while in the great majority of the disinfection done to prevent the spread of epidemic disease, measures that fall far short of sterilization will suffice. For instance, in the fumigation of a room against plague, tuberculosis, typhoid fever, cholera, and the like diseases due to non-spore-bearing organisms, it is immaterial if the dust on the ledges contain living subtilis and spores of the common moulds found in the air, or other hardy saprophytic forms of life, so long as the pathogenic bacilli are dead.

A great deal may be learned by a thorough inspection. To be sure, we cannot see the germs with our unaided vision, but we can see the dirt and moisture and other conditions that present a favorable medium for the growth and multiplication of the pathogenic micro-organisms. While the old idea that filth and unsanitary conditions breed disease, *de novo*, is wrong, it is nevertheless true that these conditions keep the infectious principles alive and favor their propagation. It is therefore plainly the duty of the disinfector not only to destroy the actual infection, but also to eradicate all the conditions that would act as breeding-places and disseminators of infection.

Fig. 5.



Common Molds with Their Spores.—(*Williams, after Baumgarten.*)
a. Penicillium glaucum. *b.* Oïdium lactis. *c.* Aspergillus glaucus. *d.* The same more highly magnified. *e.* Mucor mucedo.

The disinfection of rooms, baggage, ships, and objects that have been exposed to infection must of necessity be greatly in excess of the actual requirements. This is one of the difficulties met with in attacking an invisible foe. A room might readily be disinfected and rendered safe by applying a few gills of one of the germicidal solutions to a small spot or a limited area; but as we cannot see the germs, it is necessary to apply our disinfecting agents to every inch of surface of the room and all its contents, in order not to miss that particular infected spot. As our knowledge of infection becomes more exact, our processes of disinfection become more precise. At first disinfection was directed by a shotgun process, in a general sort of blunderbuss way, against everything; but now that we know the habits and habitat of each one of the particular micro-organisms, we can concentrate our efforts with more exactness upon the particular object or media liable to infection, with every assurance of eradicating the danger.

In other words, it is quite as important to know what to disinfect as how to disinfect, and a very thorough knowledge of the subject of the causes and modes of transmission of the communicable diseases is the most useful weapon the disinfector has in his fight against the spread of infection.

The stress of modern activities demands disinfecting processes that are instantaneous in their action, all-pervading in their effects, cheap, harmless, and free from any unpleasant odors that might offend the senses of the fastidious. Such perfect disinfectants are not known. It requires time, money and the expenditure of well-directed and intelligent energy to accomplish satisfactory disinfection.

CHAPTER I.

PHYSICAL AGENTS.

Sunlight — Electricity — Burning — Dry Heat — Boiling — Steam.

SUNLIGHT. Sunlight is an active germicide. It destroys spores as well as bacteria. The importance of the sun's rays in destroying or preventing the development and growth of micro-organisms in nature cannot be overestimated.

Unfortunately, the sunshine is so uncertain, and the force of the sun's rays so variable and their disinfecting power so superficial, that it cannot be depended upon as an aggressive measure in attacking infection in rooms, ships and confined spaces.

Sunshine comes more under the purview of the sanitarian than under that of the disinfector, but the latter can always use it to advantage in supplementing his other methods, especially in out-of-the-way localities. Rooms and objects may always be sunned and aired with advantage after disinfection.

The different rays of light have very different effects upon germ life. The blue, violet, and ultra-violets—that is, the more refrangible chemical rays of the spectrum—are the only ones possessing germicidal power. The red and yellow rays are practically inert in this regard.

The nature of the source of light seems to have little influence upon the result, it being more a question of intensity.

Even diffused light retards the growth and development of micro-organisms, and if strong enough may finally kill them. Electric light is also effective, but in a much diminished degree. The Röntgen rays (X-rays) have no bactericidal properties.

The time required for the light to arrest the multiplication and to cause the death of the different germs is far from being definitely fixed. There are many conditions besides the brightness of the light, such as moisture, temperature, the transparency, composition, thickness of the media, etc., to aid or hinder the effect of the rays. The time also varies with the different micro-organisms. The germs of plague and cholera die more quickly than those of tuberculosis. Spores are much more resistant to the influence of the sun's rays than the bacterial cells themselves. For example, it usually requires about thirty hours' sunning to kill an anthrax spore, while the anthrax bacillus is killed in one or two hours under the same conditions.

On account of all these facts, the published figures upon the time required to destroy germs in the sun have only a relative value. A few instances are given to illustrate the time required for the sunlight to destroy some of the more important pathogenic bacteria:

Buchner and Mink * found that it required an insolation of one hour to sterilize a water containing a suspension of *B. coli communis*.

Pansini † has observed the sun kill the *Bacillus anthracis* in cultures of bouillon in from one to two and a half hours. The moist spores died in from one-half to two hours, and the dried spores in from six to eight hours.

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* Buchner, "Ueber den Einfluss des Lichtes auf Bacterien," "Centralbl. für Bakt.," XII, 1893.

† E. Mace, "Traité Pratique de Bacteriologie," Paris, 1901, p. 82.

Janowsky * states that the typhoid bacillus resists about six hours' exposure to sun.

Ledoux-Lebard † reports that the bacillus of diphtheria exposed dry and in a very thin film to diffused light is killed in twenty-four hours.

According to Koch and Migneco,‡ the tubercle bacillus commences to lose its virulence after three hours' exposure to sunlight, and is often killed in five to seven hours, depending upon the thickness of the layer of the material in which it is exposed.

Rosenau § found that the plague bacillus exposed to the direct action of the sunlight dies in half an hour, provided that the temperature in the sun is above 30° C.

The higher the temperature, the more energetic is the action of the sunlight. The effect of moisture is somewhat peculiar. Dry spores live much longer in the sunlight than moist ones, whereas it is well known that desiccation hastens the death of the bacteria themselves. Before killing them, the sun's rays often attenuate the virulence of bacteria. The effect of the sunlight, at best, is very superficial upon opaque objects. In clear solutions or water it penetrates some distance.

Just how the light kills is difficult to explain satisfactorily. That the action is chemical seems likely from the fact that it is the ultra-violet rays of the spectrum that are endowed with this power.

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* Janowsky, "Zur Biologie der Typhusbacillen," "Centralbl. für Bakt.," VIII, 1890.

† Ledoux-Lebard, "Action de la luminere sur le bacille diphtherique," "Arch. de Méd. Exper.," 1893.

‡ Migneco, "Azione della luce solare sulla virulenza dello bacillo tuberculare," "Anali d'Igine sperimentale," V, 1895.

§ Rosenau, "The Viability of the Bacillus Pestis," Bulletin No. 4, of the Hygienic Laboratory, Marine Hospital Service.

Downes and Blunt[*] emphasize the importance of free oxygen in the influence of light upon bacteria. They state that without the presence of free oxygen light seems to have no germicidal power.

Richardson,[†] and also Dieudonne,[‡] showed that in cultures of bacteria the light in the presence of water and oxygen causes a production of hydrogen peroxid, which is well known to have strong disinfecting powers.

The recent work of Novy indicates that organic hyperoxids are produced under certain circumstances in fluids by the action of the sun's rays. These hyperoxids, especially acetozone, have been shown to be among the strongest germicidal substances known.

All the workers in this line agree upon the strong germicidal power of the sun's rays, and its importance in nature; but, unfortunately, the laboratory results can only be used to a limited extent by the disinfector in his practical work.

The disinfecting power of the sunlight exerts its effects only upon the surfaces exposed directly to the light, and even here the results are apt to be unequal, as Esmarch pointed out. This is easy to understand when we recall how many circumstances may modify this power of the solar rays.

ELECTRICITY. The action of electricity on bacterial life has been studied by various experimenters, who have arrived at contradictory results. Some very extravagant claims have been made for the effect of the various electric currents, but recent work has shown these claims to have been founded on error. It appears that electric currents have little germicidal action in themselves, and that the apparent effects are due either to the heat generated by the current or to electrolytic action. Electricity has very little use in practice as a disinfectant.

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[*] "Proceedings of the Roy. Soc. of London," vol. XXVI.

[†] "Jour. Chem. Soc.," 1893, I, 1109–1130.

[‡] "Arb. aus. d. kais. Ges.-Amte," Bd. IX, 1894.

Hermite * used the product of electrolysis for the sterilization of sewage. He added sea-water (sodium chlorid) to the sewage, and the electrolytic action caused the formation of hypochlorite, which has well-known germicidal action.

Webster † adds chlorids to sewage and uses iron plates as electrodes, with the result that ferrohydroxid is produced by electrolysis. It is evident, as pointed out by Zeit, that it would be simpler to add the hypochlorite or the ferrohydroxid directly to the sewage.

In other words, the effect of electrical currents upon bacteria seems to be a purely chemical one, in the case of antiseptic substances being formed by electrolytic decomposition; or a thermal one in the case of the production of heat which so frequently attends the discharge of electric currents.

Röntgen or X-rays have no direct bactericidal properties. The clinical results obtained by these electric discharges must find their explanation in other factors, possibly the production of ozone, hypochlorous acid, organic hyperoxids, necrosis of the deeper layers of the skin or phagocytosis.

BURNING.

Fire is the great purifier. Burning has, however, a very limited range of usefulness in practical disinfection. A disinfector is seldom justified in burning an article against the wish of its owner, for we now possess other methods by which any

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* F. Robert Zeit, "Effect of Direct, Alternating, and Tesla Currents and X-rays on Bacteria," "Jour. Amer. Med. Assoc.," Nov. 30, 1901.

† "Jour. Soc. Chem. Ind.," p. 1093; "Jour. Amer. Med. Assoc.," Nov. 30, 1901, p. 1432.

object may be rendered safe so far as its power of conveying disease is concerned. In actual practice, however, the disinfector comes across a great mass of rubbish and articles of little value, that he will find safer and cheaper to burn than to disinfect.

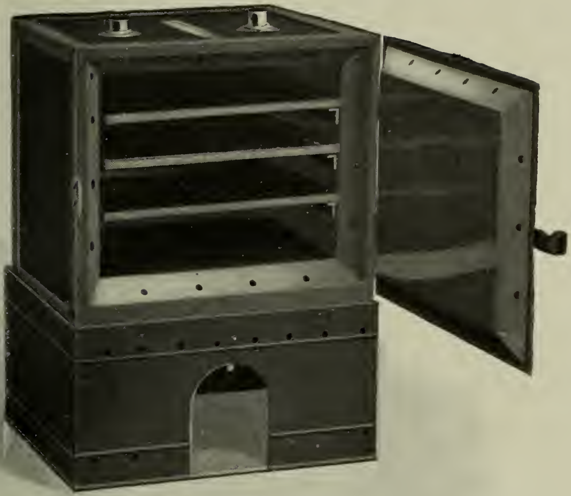
The burning of garbage and refuse is the safest means of disposing of these substances from a sanitary standpoint, especially in districts where pestilential disease prevails. From the same standpoint the cremation of bodies dead of a communicable disease is by far the safest means of preventing the spread of infection from this source. The burning of garbage and refuse requires special furnaces, if large amounts are to be dealt with. Small amounts may effectively be disposed of by an improvised fire of coal, wood, or petroleum.

DRY HEAT. A temperature of 150° C., continued for one hour, will destroy all forms of life, even the most resisting spores. It is easy to maintain this temperature in an apparatus of special construction known as a hot-air or dry-wall sterilizer. Glassware and many objects that will stand this degree of heat are sterilized in an oven of this kind in bacteriologic laboratories and in surgical clinics.

A dry heat somewhat less than 150° C. is sufficient to destroy many pathogenic bacteria, especially the non-spore-bearing variety, such as plague, cholera, diphtheria, tuberculosis, pneumonia, and most of the epidemic diseases to which man is liable. Dry heat is not so reliable a disinfectant as moist heat, especially as it lacks penetration, and is injurious to fabrics.

Most materials will bear a temperature of 110° C. (about 230° F.) without much injury, but when this temperature is

FIG. 6.



HOT-AIR STERILIZER.

exceeded, signs of damage soon begin to show. Scorching occurs sooner in woolen materials, such as flannels and blankets, than with cotton and linen. The overdrying renders most fabrics very brittle, but this injury may be lessened by allowing the materials which have been subjected to dry heat to remain in the air long enough to regain their natural degree of moisture before manipulating them.

The ordinary household cooking oven is as good as any specially contrived apparatus for the disinfection of small objects by dry heat. In the absence of a thermometer it is usual to heat the oven to a point slightly below the temperature necessary to brown cotton, and expose the objects no less than one hour.

Dry heat fixes many stains, so that they will not wash out. This is especially marked with albuminous materials coagulable by heat, and the method should not be used for the disinfection of fabrics and objects soiled with blood, sputum, excreta, or similar substances.

BOILING.

Boiling is such a commonplace, everyday process that it is often neglected in practical disinfection, despite the fact that it is one of the readiest and most effective methods of destroying infection of all kinds. An exposure to boiling water at 100° C., continued half an hour, will destroy the living principles of all the known infectious diseases, even very resisting spores. To be sure, there are a few spores that have shown a remarkable resistance to boiling water and streaming steam in laboratory experiments, but these are exceptions, and may be disregarded in practical work. In fact, a degree of moist heat much lower than the boiling-point of water is effective against the great majority of known infectious agents. A temperature of 70° C. will destroy within half an hour the germs of cholera, diphtheria, plague, tuberculosis, typhoid fever, pneumonia, erysipelas, and practically all the diseases due to non-spore-bearing bacteria. Boiling kills these bacteria at once.

To destroy the infection of anthrax, tetanus and other sporulating bacteria, two hours' exposure to moist heat at 100° C. is essential.

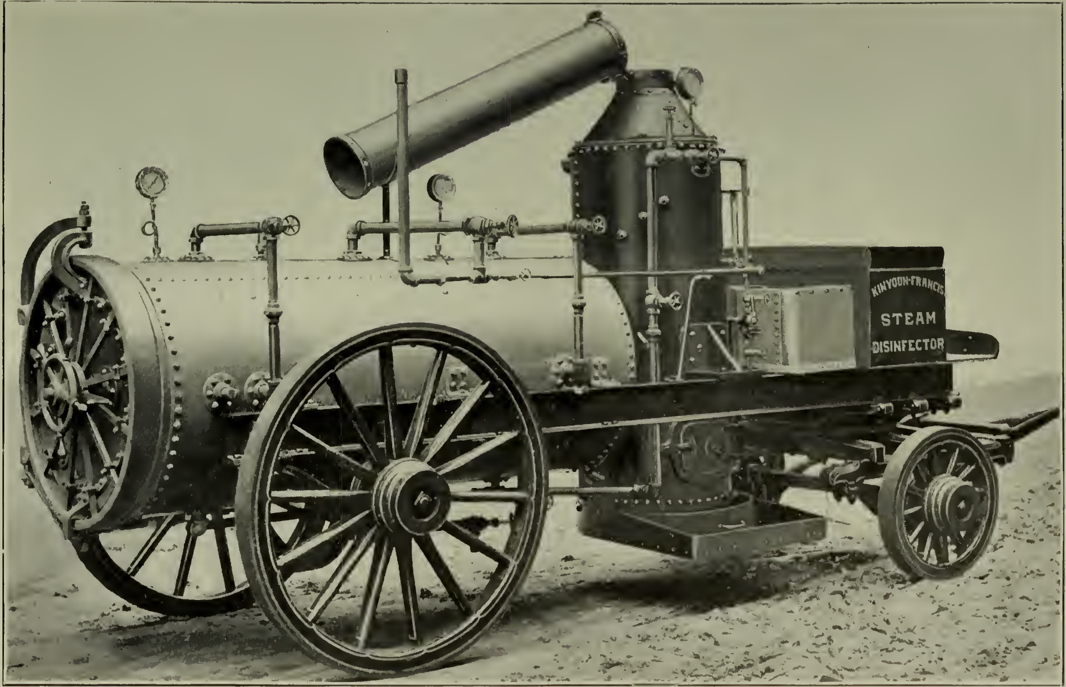
Boiling is particularly applicable to the disinfection of bedding, body linen, towels and fabrics of many kinds; to kitchen- and tableware; to cuspidors, urinals and a great variety of objects. Surfaces, such as floors, walls, beds, furniture, etc., may be effectively disinfected by mechanically cleansing them with boiling water. The efficacy of boiling water, especially when used under such circumstances, is greatly increased by the addition of corrosive sublimate, carbolic acid, or any one of the soluble germicidal agents. The addition of lye, borax, or a strong alkaline soap greatly increases the penetrating power of boiling water, when applied to surfaces soiled with organic or oleaginous matters.

In using boiling water for the disinfection of bright steel objects or cutting instruments, the addition of 1 per cent. of an alkaline substance (bicarbonate of soda) will prevent rusting and injury to the cutting edge.

STEAM.

Steam is the most valuable disinfecting agent we possess. It is reliable, quick, and may be depended upon to penetrate deeply. It does more than disinfect; it sterilizes. Bacteria are killed instantly, spores are killed in a few minutes, and it may therefore be used to destroy the infection of any one of the communicable diseases.

Fig. 7.



Portable Steam Disinfecting Cylinder.

Either streaming steam or steam under pressure is used in practical disinfection.

Streaming steam has the same disinfecting power as boiling water, and an exposure of half an hour is sufficient to kill very resistant spores.

Steam under pressure is a more powerful germicide than streaming steam. At a pressure of 15 pounds to the square inch steam has a temperature of approximately 120° C., and will surely sterilize in twenty minutes. At 20 pounds pressure it has a temperature of approximately 125° C., and will sterilize in fifteen minutes.

For the disinfection of bedding, clothing, fabrics of all kinds, and a great variety of other objects, steam is applicable and does no particular harm, provided the precautions described more in detail under each method are taken.

Steam is very apt to shrink woolens and injure silk fabrics. It ruins leather, fur, skins of all kinds, also rubber shoes, mackintoshes, and similar articles made of impure rubber.

It is important, in disinfecting with steam, whether with streaming steam or steam under pressure, to expel the air from the apparatus, for the air, being a poor conductor of heat, forms dead spaces and prevents the steam from coming in direct contact with the articles to be disinfected, thereby defeating the object to be attained. As steam is lighter than air, the latter can best be expelled from the apparatus or inclosure by admitting the steam from above, in which case the descending column of steam forces the air out at the bottom. If the steam is admitted from the bottom, it swirls up, making a nearly uniform mixture with the air, and while the temperature quickly rises throughout the inclosure, the air escapes mixed with the steam, so that it takes a very long time and an unnecessary waste of steam to drive out the contained air.

STREAMING STEAM.

In streaming steam we have an efficient and absolutely reliable disinfecting agent for many practical purposes. In the laboratory and the surgical clinic it is used in the Arnold steam sterilizer and the Koch steamer. It is also used on an extensive scale in specially devised apparatus in many of the large disinfecting establishments in Germany.

Bacteria are killed almost instantly by exposing them directly to streaming steam; however, allowance must be made for the time it takes for the steam to penetrate and heat the object to 100° C., so that it is usual to leave them in the steam sterilizer one hour. The time required to heat the apparatus itself must, of course, always be taken into account.

Spores are occasionally found that resist several hours' steaming. Such instances are not only exceptional, but are in almost all cases the spores of non-pathogenic bacteria. For example, Globig* found spores of a particular variety of the hay bacillus that required five and a half to six hours' exposure to streaming steam at a temperature of 100° C. in order to kill them. And Christen† isolated a bacillus of the same variety whose spores withstood 16 hours' exposure to streaming steam at 100° C. It is fortunate that instances of such highly resistant spores are exceptional, and it is also fortunate that the great majority of the communicable diseases from which man suffers are due to non-spore-bearing bacteria.

In using streaming steam for the disinfection of such diseases as anthrax, tetanus, malignant edema, symptomatic anthrax, the gas-producing anaerobes, and other spore-bearing infections, it is necessary to prolong the exposure to not less than two hours after the temperature reaches 100° C.

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* "Zeitschr. für Hygiene," Bd. III, 1887, p. 333.

† "Mittheil. a. d. klin. u. med. Inst. d. Schweiz," III, Heft 2, 1895.

Disinfection with streaming steam may be accomplished in many ways without the use of special apparatus. For rough-and-ready work on the railroad the objects to be disinfected may be hung up in a freight car and the steam brought from the locomotive. On board a vessel one of the compartments above the water line may be filled with steam from the boiler.

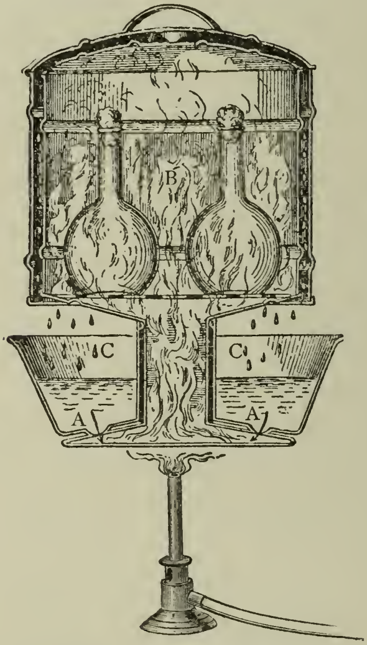
Fabrics and objects may be disinfected in any rough structure wherever a boiler is found to furnish the steam. Such a structure need not be tight, for the streaming steam escaping from the cracks produces a circulation and favors penetration.

In the household, small objects, body and bed linen, and other fabrics may be thoroughly disinfected by streaming steam by placing a large pot or wash-boiler on the kitchen fire, and arranging broom handles across the top to hold the materials to be disinfected. The whole should be covered with a sheet or cloth to retain the heat, and steamed for an hour or longer, depending upon the degree of penetration required and the energy with which the water boils. The addition of some salt to the water will raise the boiling-point, and the steam will therefore be given off at a higher temperature than 100° C., which is a distinct advantage.

THE ARNOLD STEAM STERILIZER.

The Arnold steam sterilizer is the best and most economic instrument of its kind for the disinfection of small objects by streaming steam, without pressure. This form of apparatus depends upon the heating of a small amount of water, which descends through the apertures (A), and which rises as steam into the sterilizing chamber (B), where it condenses, to fall back into the pan (C). The water in the pan (C) soon becomes hot, so that a great saving in time and fuel is effected. This form of sterilizer, as ordinarily sold on the market, is opened by removing the hood and lid, which should be done as soon as the process is completed, in order to prevent the accumulated steam in the chamber condensing upon and wetting the exposed objects.

FIG. 8.

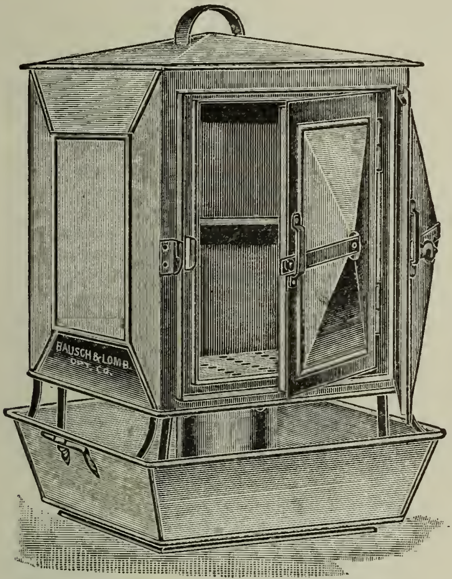


SECTION THROUGH AN ARNOLD STEAM STERILIZER.

The sterilizer may be heated on the kitchen fire, or over a gas flame or oil lamp, comparatively little heat being required.

An improved form of the Arnold steam sterilizer, known as the Boston Board of Health pattern, is a much more convenient design than the older form of apparatus with the hood. As will be seen from the accompanying illustration, this sterilizer has two doors opening on the side, one in the hood and the other in the sterilizing chamber itself.

Fig. 9.

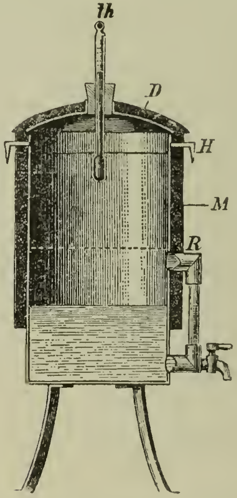

BAUSCH & LOMB.
OPT. CO.

Arnold Steam Sterilizer.

The Koch Steamer.

The Koch steamer is an apparatus designed for the disinfection of objects in streaming steam without pressure. It consists simply of a metal vessel, usually made cylindric in shape, and covered with felt or some non-absorbent material. The steamer is furnished with a water gage (*R*, Fig. 10) and faucet, and a thermometer (*th*). The lid (*D*) is also covered with felt and does not fit hermetically, or has a small opening so that the steam may escape, which favors the circulation and penetration, and prevents the pressure rising. The steamer is partly filled—about one-third—with water, as shown on the diagram (Fig. 10), and the heat is applied to the bottom of the kettle by means of a Bunsen gas burner or any other form of flame, sufficiently hot to boil the water energetically.

FIG. 10.

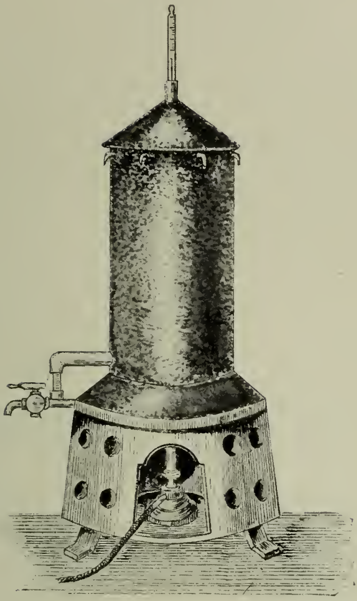


SECTION THROUGH KOCH STEAMER.

The articles to be disinfected are placed on a special carrier that fits in the cylinder above the water, or they may be hung in by cords from the hooks (*H*).

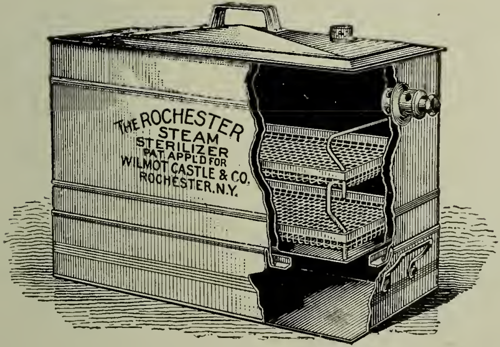
While this form of disinfector is commonly small in size for laboratory work, it is also built on a scale sufficient to hold mattresses, bedding, and clothing, and may be used for the disinfection of baggage upon a large scale. In the larger sizes it is advisable to use a solution of salt, in order

FIG. 11.



KOCH STEAM STERILIZER.—(*From Williams.*)

FIG. 11A.

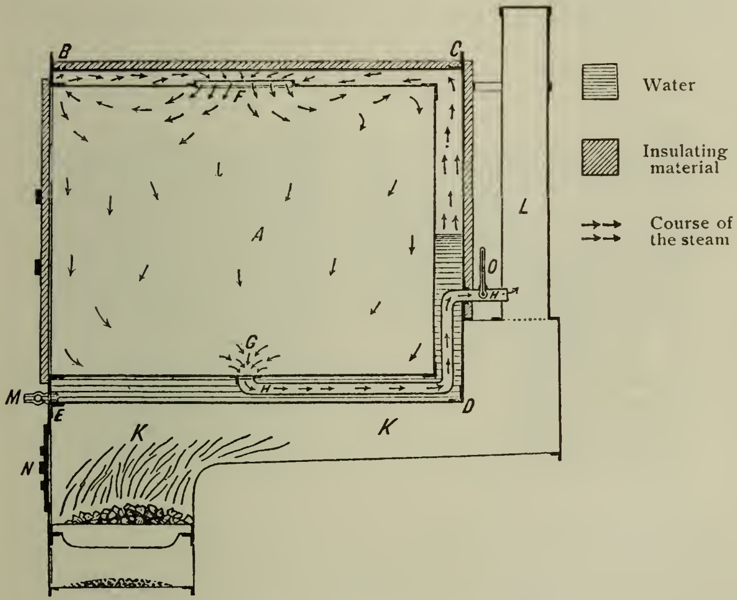


A COMBINATION STERILIZER FOR USE WITH STREAMING STEAM, BOILING WATER, OR HOT WATER.

to insure the streaming steam at the exit having a temperature of 100° C.

As the steam cannot escape freely, and as the loss by heat is guarded against, a uniform temperature of 100° C. may be obtained from the surface of the water to the lid; and as the lid is not tight, the pressure does not rise.

FIG. 12.



STEAM DISINFECTOR OF VAN OVERBEEK DE MAYER.

The Koch steamer is an efficient and economic method of disinfection, although it is more cumbersome, requires more fuel, and takes a longer time to heat than the Arnold steam sterilizer.

A good form of apparatus depending upon streaming steam as its disinfecting agent has been designed by Dr. G.

Van Overbeek de Mayer. This steamer is applicable for the disinfection of bedding and baggage in quantities, for which purpose it is made in large sizes. The principles of construction and action are shown on the accompanying diagram (Fig. 12).

The water is heated by a coal or wood fire, and the steam rises as shown by the arrows, to enter the top of the chamber at *F*. From here it descends, displacing the air, and flowing through the objects exposed in the chamber *A*, finally escaping at the outlet *G*. The steam is prevented from condensing in the outlet pipe, *H*, by the hot water which surrounds it, until it escapes into the stack, *L*.

FIG. 13.

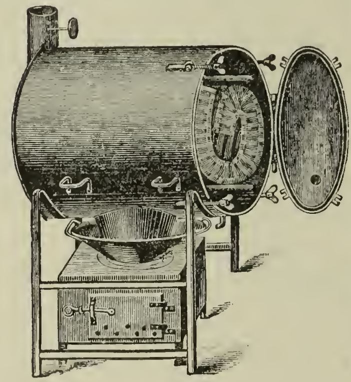
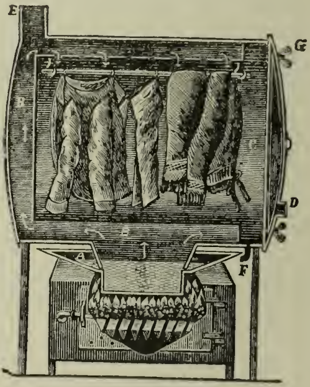


FIG. 14.



A modified form of this apparatus, designed by Merk, is shown in the accompanying illustrations, figures 13 and 14.

STEAM UNDER PRESSURE.

Steam under pressure, or superheated steam, acts more rapidly and penetrates more deeply than streaming steam at 100° C. Steam at a pressure of one atmosphere, or temperature of 120° C., will sterilize with certainty in fifteen minutes' time. At a temperature of 115° C. it may be depended upon to sterilize in twenty minutes. The following table, according to Globig,* shows graphically the increased power of steam under pressure, upon an exceptionally resistant subtilis spore:

In streaming steam at 100° C., subtilis spore killed in 5½ to 6 hours.
In steam under pressure at 109°–113° C., subtilis spore alive after 45 minutes.
“ “ “ “ “ 113°–116° C., “ “ killed in 25 “
“ “ “ “ “ 112°–123° C., “ “ “ “ 10 “
“ “ “ “ “ 126° C., “ “ “ “ 3 “
“ “ “ “ “ 127° C., “ “ “ “ 2 “
“ “ “ “ “ 130° C., “ “ “ immediately.

Superheated steam is very useful in the laboratory and the surgical clinic to obtain absolute sterilization in a much shorter time than is possible with streaming steam. On account of the great certainty with which steam under pressure acts it is a favorite method in practical disinfection, and apparatus for applying this process on a large scale have reached a high degree of perfection. The smaller forms of apparatus are known as digesters, or autoclaves, the larger ones as steam disinfecting chambers or cylinders.

The Autoclave. The autoclave, digester, or steam pressure sterilizer consists of a kettle usually made of copper and sufficiently strong to withstand the pressure. Water is placed in the kettle and the heat is applied to the bottom, usually by means of several Bunsen gas jets. The apparatus is surrounded as high as the shoulder, where the lid is attached, by a metal jacket which serves the purpose of bringing the heat of the flame in contact with the entire surface of the kettle. The lid is made to fit tightly by means of screw bolts and a rubber gasket. The lid carries the thermometer, the pressure gage, and the safety valve, and a small opening provided with a stop-cock for the purpose of expelling the air. If all the air is not expelled from the apparatus the "dead spaces" will have a much lower temperature than that registered on the thermometer; for instance, the steam itself may register a temperature of 130° C. while the fluids exposed may only reach 70° to 80° C. Therefore, in using this form of sterilizer it is customary to allow the steam to escape in full force for several minutes from the opening (x, Fig. 15) before permitting the pressure to rise.

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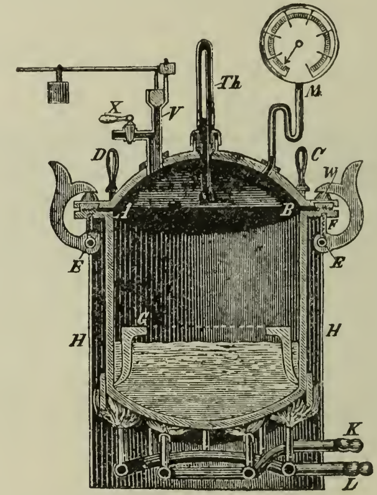
* "Zeitschr. für Hygiene," Bd. III, 1887, p. 331.

Fig. 15.



Section through Autoclave.

In the sterilization of liquids, for which this apparatus is frequently used, it is important, at the conclusion of the process, not to take off the lid or open the valve, or in any other way release the pressure until the apparatus has cooled; otherwise the condensed steam causes a diminished pressure, in which the superheated liquids will boil energetically, resulting in a bubbling over, a blowing out of stoppers, or bursting of the flasks. It is therefore necessary to wait until the pressure is zero, as registered on the gage; or better, until the condensing steam produces a partial vacuum and the air is automatically sucked in through the vacuum valve, which is sometimes fitted in the lid of the apparatus for this very purpose.

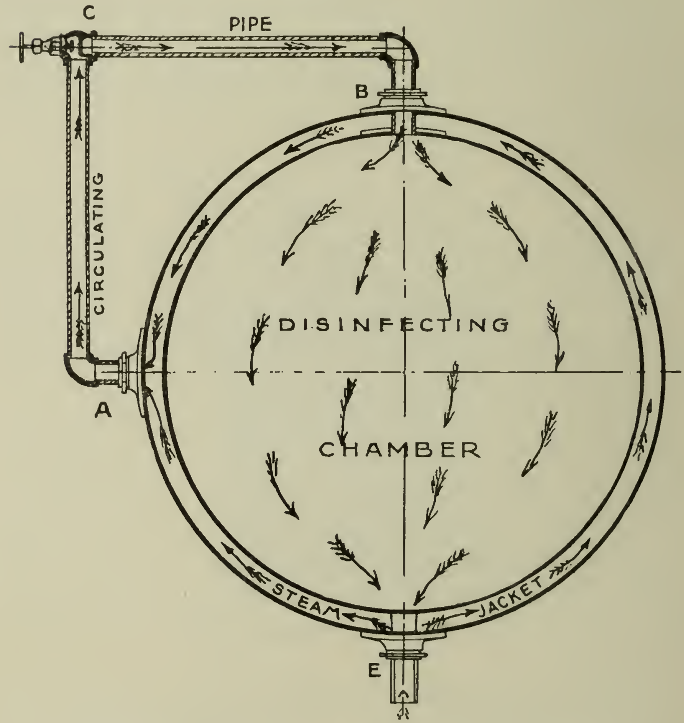
The Steam Chamber.

The steam disinfecting chamber has reached a high degree of usefulness through the gradual perfection of the details of its working parts. These chambers are somewhat complicated and their mechanical construction must be mastered in order to insure reliable results.

The Kinyoun-Francis steam disinfecting chamber is most widely used in the United States, and has the advantage of being applicable to the disinfection of large quantities by a variety of methods. It may be used with streaming steam or with steam under pressure; with formaldehyd gas alone or with this gas in combination with dry heat; and finally with various combinations of these methods, with or without a vacuum.

The disinfecting chamber itself may be rectangular or cylindric in shape, the former giving more effective space for the objects to be disinfected, the latter being a stronger and cheaper method of construction. The chamber is built of an inner and an outer shell, forming a steam jacket, as shown in figure 16. The steam jacket serves several purposes. By heating the contents of the disinfecting cylinder before the steam is turned in, it avoids condensation; during the process of disinfecting it helps keep the steam in the chamber "live," thereby preventing the wetting of the objects being steamed; after the disinfection is finished and the chamber opened the heat from the steam in the jacket

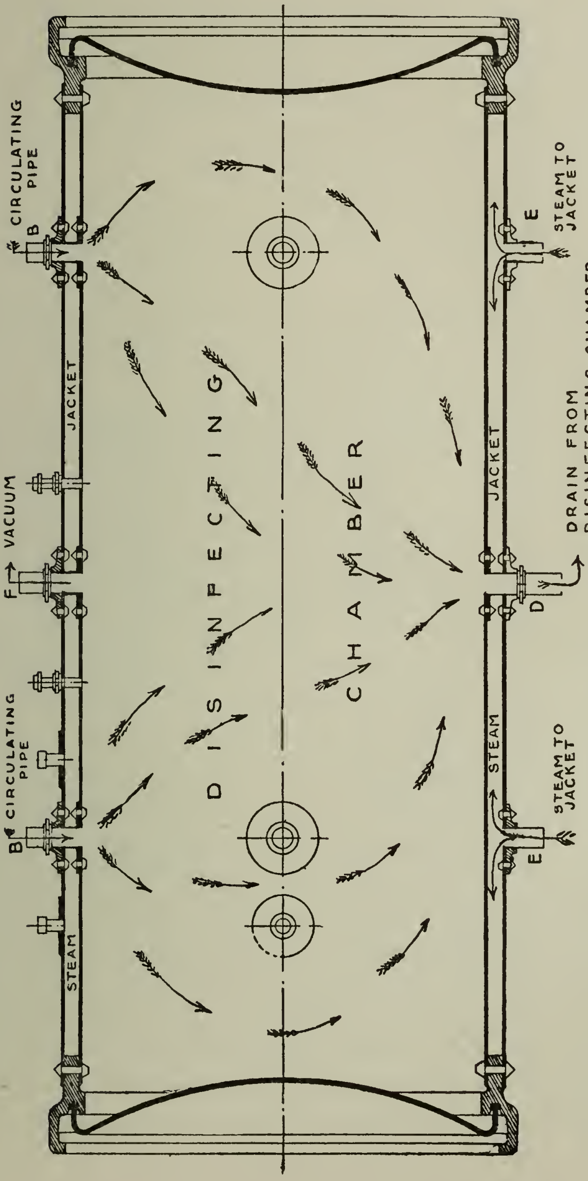
FIG. 16.



CROSS-SECTION THROUGH STEAM DISINFECTING CHAMBER.

may be used to dry the objects which have been exposed. Therefore, in using this apparatus for disinfecting with steam, either with or without pressure, the steam is kept circulating in the jacket from the beginning to the end of the process. In disinfecting with formaldehyd gas com-

Fig. 17.



Longitudinal Section through Steam Disinfecting Chamber.

bined with dry heat, the steam is kept in the jacket throughout the process, so that the gas and the air contained within the cylinder may be kept at the required temperature.

In the jacket the steam has a perfectly free circulation, so that the entire disinfecting cylinder, with the exception of the doors, is surrounded by live steam.

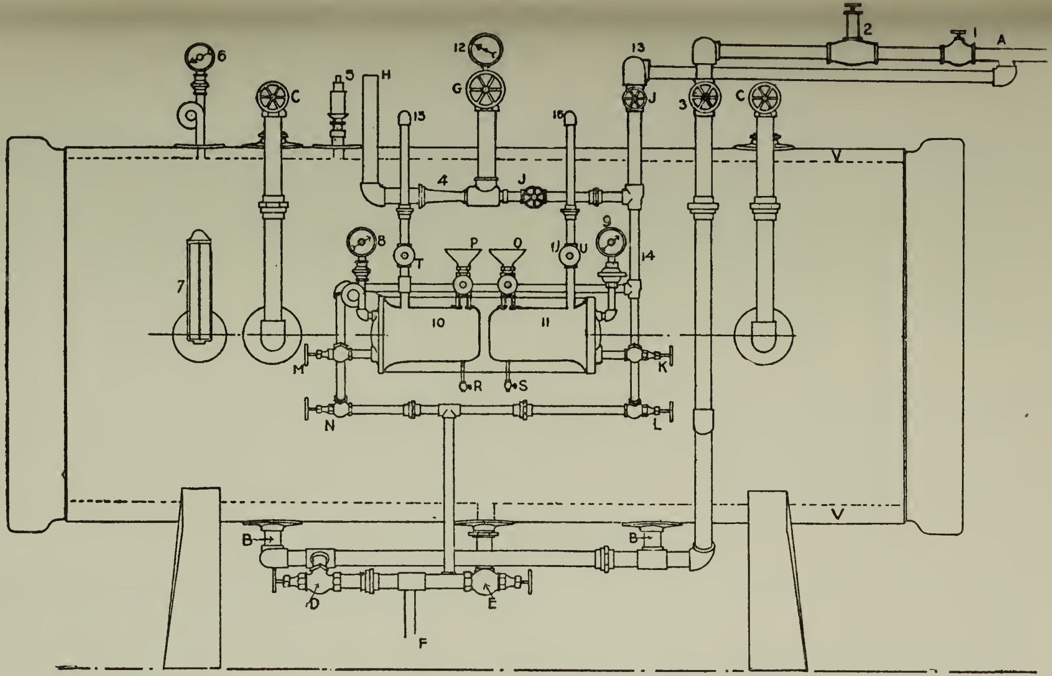
The outer shell of the jacket is protected with a covering of sectional magnesia, asbestos, or some other non-conducting substance.

The steam from the boiler passes through the main steam pipe A (Fig. 18) to the pressure-reducing valve (2) and thence to the bottom of the jacket at B, B.

Into the disinfecting chamber itself the steam can only be admitted from the jacket, through the circulating pipes, A, C, B (Fig. 16), and after circulating through the disinfecting chamber in the direction as shown by the arrows, is allowed to pass out with the drip through the drain D (Fig. 17). Upon the completion of the process the steam may be blown off through the vacuum pipe F, but this outlet should not be used during the steaming, because the desired circulation would not be obtained.

It will be noticed that the steam is admitted to the bottom of the jacket, but to the top of the disinfecting chamber, which is designed to favor the expulsion of the air through its outlet at the bottom, by means of the descending column of steam. Therefore, in order to expel all the air and fill the chamber with steam, it is essential to open the drain D (Fig. 17) while the steam is entering through B, B, and this outlet, D, should not be closed until the steam escapes freely. In using the vacuum attachment to expel the air contained in the apparatus, the *modus operandi* is somewhat different.

A partial vacuum may be obtained in steam chambers of this type with the ejector (4, Fig. 18). The object of the



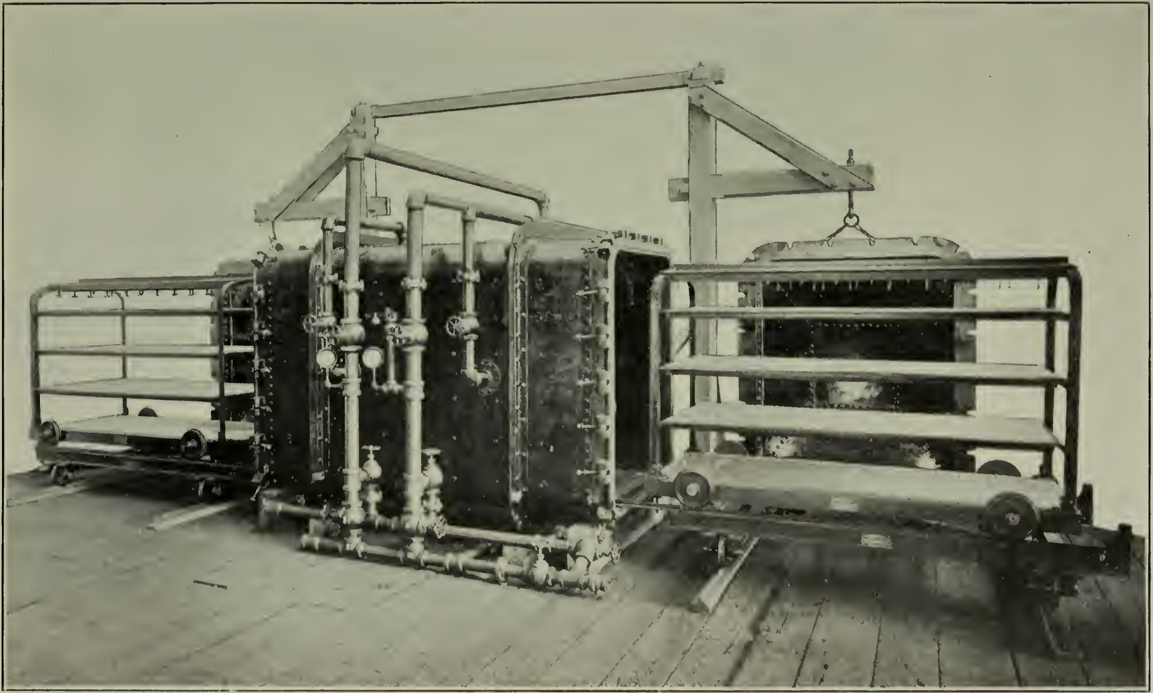
KINYOUN-FRANCIS DISINFECTING CHAMBER.

1. Valve admits steam from boiler to reducing valve. 2. Reduces steam to pressure used in chamber. 3. Valve admits reduced steam to jacket at bottom. 4. Vacuum apparatus. 5. Safety valve. 6. Steam pressure gage. 7. Thermometer. 8. Formaldehyd pressure gage. 9. Ammonia pressure gage. 10. Copper formaldehyd retort. 11. Steel ammonia retort. 12. Vacuum gage. 13. High-pressure steam pipe to vacuum apparatus. 14. Branch to formalin and ammonia retorts. 15. Copper pipe conducts formaldehyd gas to chamber. 16. Iron pipe conducts ammonia gas to chamber. A. Steam pipe from boiler. B, B. Steam pipes to jacket. C, C. Valves admit steam from jacket to chamber. D. Drip valve from jacket. E. Drip valve from chamber. F. Outboard drip and circulation. G. Vacuum valve. H. Exhaust pipe of vacuum apparatus. J. Valve admits high-pressure steam to vacuum apparatus. K. Valve admits high-pressure steam to ammonia coil. L. Drip from ammonia coil. M. Valve admits high-pressure steam to formaldehyd coil. N. Drip from formaldehyd coil. O. Filler for ammonia retort. P. Filler for formaldehyd retort. R. Drain from formaldehyd retort. S. Drain from ammonia retort. T. Valve admits formaldehyd gas to chamber. U. Valve admits ammonia gas to chamber. V. The steam jacket.

vacuum is to facilitate the penetration of the steam, which rushes into all the interstices of fabrics and inaccessible places, to take the place of the air which has been withdrawn. The ejector works upon the familiar principle of the water vacuum pump, the air being drawn or sucked along with the current. With a pressure of 80 pounds in the boiler and the valve J (Fig. 18) wide open, the ejector will produce a vacuum of 15 inches in one of the largest sized chambers in one minute, which is very much quicker than can be accomplished with the ordinary forms of piston pumps.

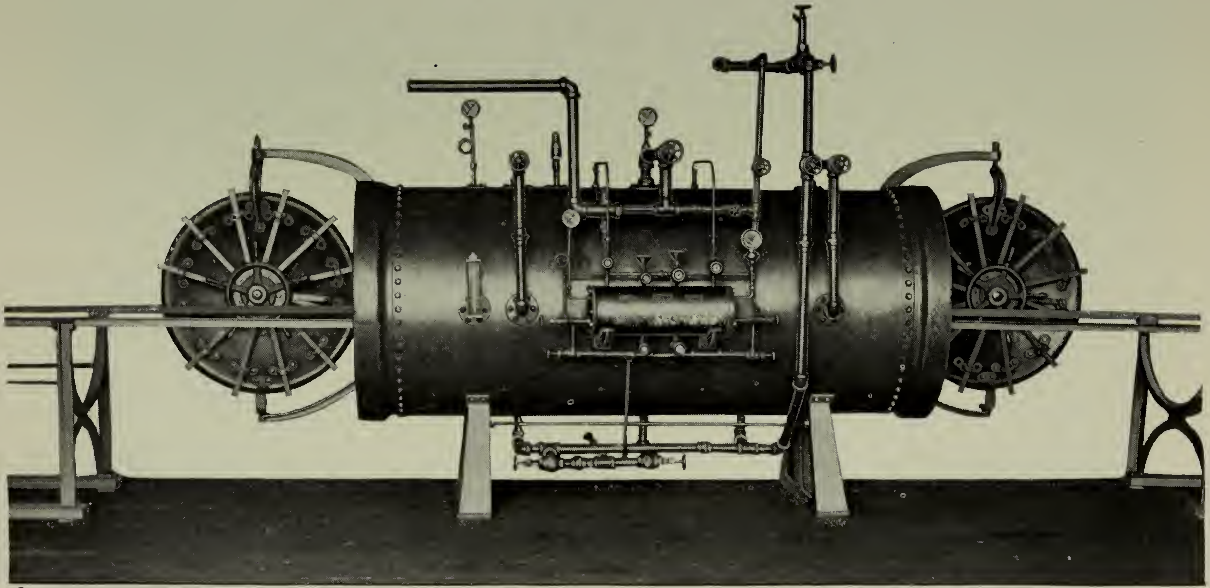
The formaldehyd attachment consists of a copper retort (10, Fig. 18), in which the formalin mixed with calcium chlorid is heated by means of a copper steam coil. This attachment does not differ in principle from the method of evolving formaldehyd gas from its watery solution mixed with a neutral salt under pressure, and any of the forms of apparatus described in the following pages (Chapter II) will answer as well as the particular retort furnished with the steam chamber, if not better. The formaldehyd retort is filled through the funnel, P, with the mixture consisting of formalin (40 per cent.), to which is added 20 per cent. of calcium chlorid and sometimes 10 per cent. of glycerin. About 10 ounces of this mixture are used for each 1000 cubic feet of air space. The steam is turned on through the valve M to the coil in the retort, and the drip from this coil passes out through the valve N. A pressure of at least 45 pounds to the square inch in the retort, as shown by the gage B, must be obtained before the gas is allowed to pass through the valve T into the disinfecting chamber. Care must be exercised at the beginning of the operation to be sure to allow the air to escape from the retort through the valve T, so that the gage will register the pressure of the gas and not the pressure of the retained air.

Fig. 19.



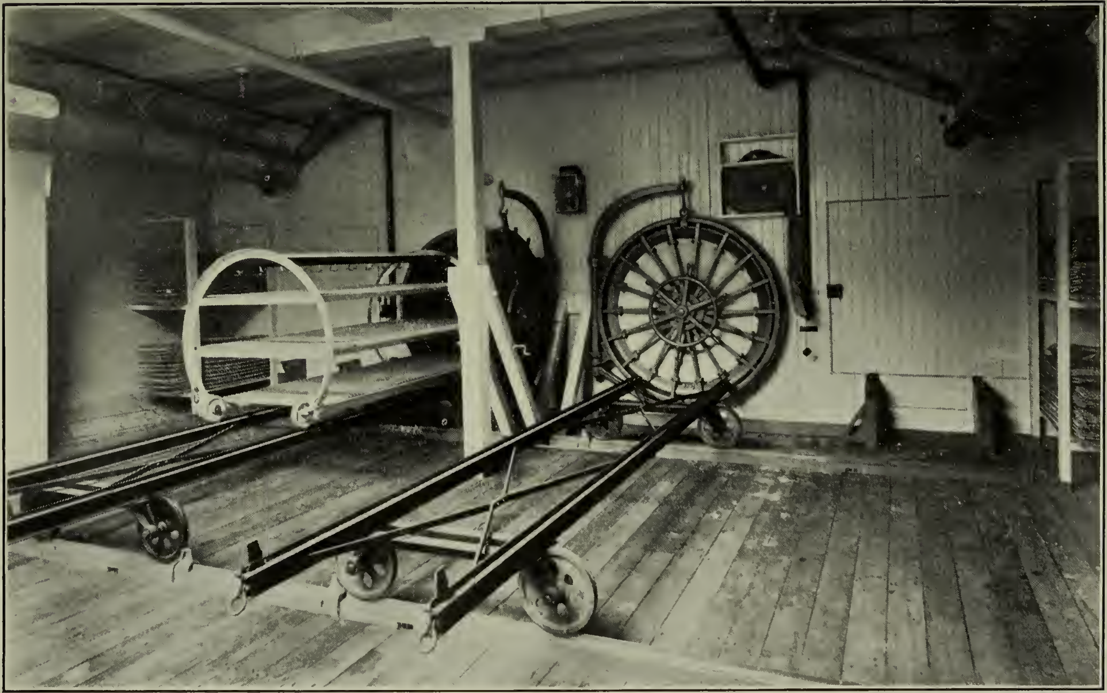
Steam Disinfecting Chamber, Illustrating the Rectangular Form.

FIG. 20.



KINYOUN-FRANCIS STEAM CHAMBER, SHOWING IMPROVED QUICK-CLOSING DOORS.

FIG. 21.



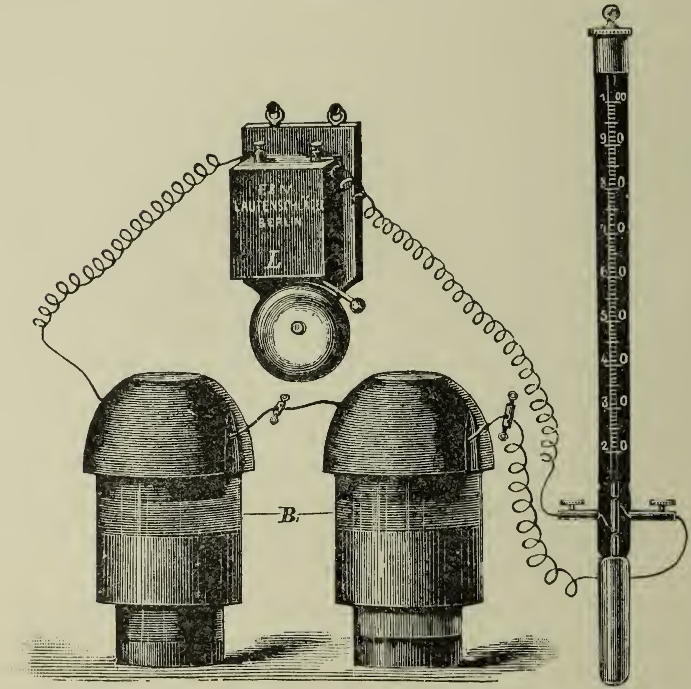
DISINFECTING STEAMER "SANATOR." VIEW IN HOLD, SHOWING THE METHOD OF INSTALLING THE STEAM CHAMBERS IN A FLOATING PLANT.

To the right of the copper formaldehyd retort is a complete duplicate in iron (11, Fig. 18), for the evolution of ammonia, which was formerly used to neutralize the formaldehyd at the completion of the process, but which is seldom used now because it is simpler to allow the gas to blow away by opening both doors of the disinfecting chamber.

The chambers are open at both ends so that the infected objects may be introduced from one side, and taken out upon the other, which diminishes the risk of reinfecting them. The chambers are closed by means of large cast-iron doors, which swing upon cranes. Formerly the doors were locked into place by means of eyes and screw bolts, but as this method is time-consuming, the doors are now provided with a series of radial bolts which are driven home by simply turning a wheel at the center. The joint between the door and the chamber is made tight by means of a heavy rubber gasket. The door should not be pressed against this gasket more firmly than is found necessary to retain the steam, otherwise the rubber will soon be rendered useless. In using the vacuum, the air pressure effectually keeps the door closed, so that it is only necessary to have it closed firmly enough at the beginning of the process to make a tight joint in order to start the vacuum.

In addition to the above-mentioned attachments, the disinfecting chambers are also supplied with a thermometer (7, Fig. 18), the stem of which is turned at right angles and protrudes through the steam jacket, so that the instrument is supposed to register the temperature of the interior of the disinfecting chamber. The thermometer, however, is so close to the jacket that it is influenced by the heat in the jacket, which is usually higher than the temperature of the interior of the chamber. The thermometer should be in the door, or differently arranged, to give trustworthy results. In disinfecting with steam under pressure, the pressure, as indicated by the gage, is a more reliable guide than the temperature registered by the thermometer. There are forms of mercurial and metallic thermometers that make an electric contact when a certain temperature is reached, and which may be connected to ring a bell. They have the decided advantage in that they may be placed anywhere within the chamber, even in the center of bundles, etc., and are more trustworthy than any form of mercurial

FIG. 22.



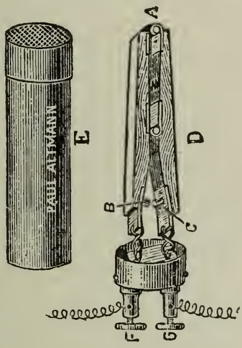
ELECTRIC THERMOMETER.

instrument fastened through the heavy metallic walls of the apparatus.

An ingenious form of thermometer, made to register when the temperature reaches 100° C., has been designed by Merk and is shown in the accompanying illustration (Fig. 23).

A small stick of the metallic substance which is supplied with the instrument and which melts at exactly 100° C., fastened at A, keeps the electrodes at B and C apart. The entire thermometer D is then placed in the box E for protection, and this is placed in the chamber, or in the inside of bundles to be disinfected. The insulated wires from F and G are connected with a battery and bell. As soon as the temperature reaches 100° C. the little metal stick melts, the contact is made between B and C, and the bell rings. This form of thermometer is more accurate than the pyrometers which depend upon the contact being made by the unequal expansion of a compound metal bar, for the reason that moisture collects upon the electrodes and an electric

FIG. 23.

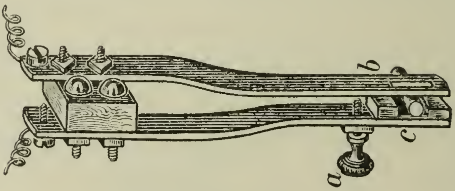


AUTOMATIC THERMOMETER.

contact is sometimes made before the metal parts actually touch, thereby giving false readings.

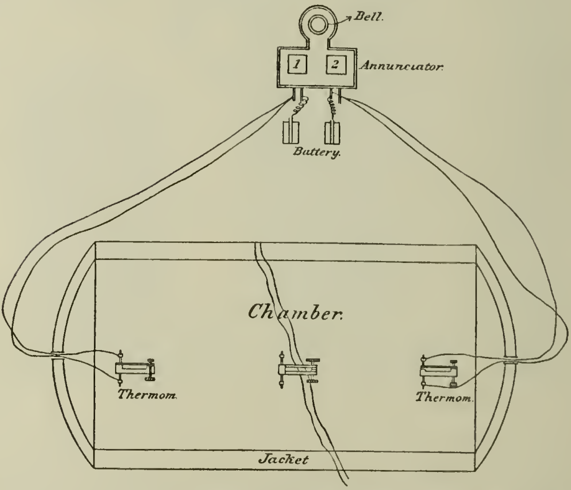
The chamber is also provided with a galvanized iron or copper hood, to prevent rust-stained drip from soiling the clothing and other objects exposed to the steam; gages to indicate both vacuum and steam pressure (6 and 13, Fig. 18); and a safety valve (5, Fig. 18) to prevent overpressure in the

FIG. 24.



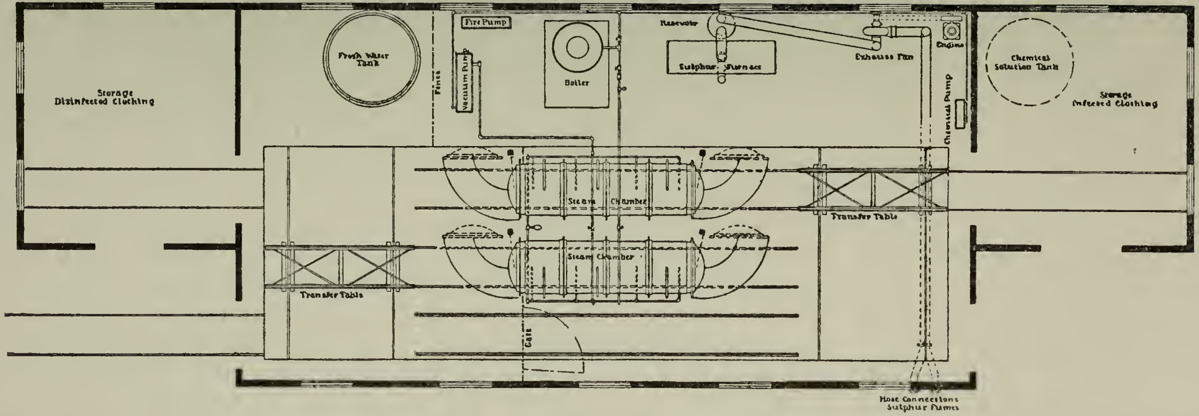
PYROMETER.

FIG. 25.



SCHEME FOR INSTALLING ELECTRIC THERMOMETER IN THE STEAM DISINFECTING CHAMBER.

FIG. 26.



PLAN SHOWING THE METHOD OF INSTALLING THE DOUBLE-ENDED STEAM CHAMBERS AT A NATIONAL QUARANTINE STATION.

chamber, the amount of pressure from the boiler being regulated by a reducing valve in the steam pipe (2, Fig. 18).

For convenience of handling the goods, cars are provided, of light wrought-iron construction, with movable trays, made of galvanized screens; also bronze hooks at the top of the car, permitting the articles to be laid upon the trays, or to be hung up on the hooks.

In the accompanying diagram (Fig. 26) the method of installing the steam chambers in the disinfecting shed of a quarantine station is shown. It will be noted that the cylinders open on both ends, and that a dividing wall running across the building separates the receiving end, where the infected objects arrive and are prepared for disinfection, from the discharging end, where the contents of the chamber are aired, dried, and repacked after disinfection.

This separation is essential where a large amount of disinfection is done for a variety of diseases, as, for example, in a municipal disinfecting establishment or at the quarantine station of a busy port. It is true that the infection of certain diseases is not apt to contaminate the surroundings, and in such cases there would be little risk in taking the disinfected articles out of the same end of the chamber from which they are put in, especially if all the surfaces are mopped with a disinfectant in the interim. But this is a risk that should not be taken; in fact, all well-regulated disinfecting plants maintain a rigid separation between the two sides, never allowing both doors of the chamber to be open at the same time, and providing two sets of workmen, one for the "infected" and one for the "disinfected" side.

Loading the Chambers.

The chambers must be loaded with care in order to obtain reliable results and to avoid injuring the articles exposed to the process. The chamber must not be stuffed full of fabrics and clothing promiscuously, nor must the packages be too large or crowded too closely, for although the vacuum facilitates the penetration of the steam, there is a limit in this regard; and it takes so much longer time for the disinfecting agents to penetrate dense packages and bundles that there is little saving in time and a distinct loss in trustworthiness.

In the steaming of clothing and expensive fabrics it is always better to hang them up than to lay them down, for they retain the folds and creases of steaming with obstinacy. They may even show the impression of the wires of the galvanized iron tray on which they have been laid. Where only a few articles are to be disinfected it is best to simply hang them on the cars provided for this purpose, but where a great amount of baggage belonging to different persons needs disinfecting it is usual to provide a number of galvanized iron wire baskets, made to fit the car. The baskets are numbered with a metal tag, and the trunk or container from which the articles were taken is given a similar number, so that confusion is avoided. It is advisable to line each wire basket with canvas, so as to protect the goods against rust stains and drip.

The steam cannot penetrate compressed bundles of rags, bales of cotton, feathers, hair, or other products which are often presented for disinfection, and it is therefore essential to open and properly expose such objects to the action of the disinfecting agent.

In the Paris municipal stations the cars are loaded in a special manner which avoids injury to the fabrics. A large piece of thick linen, whose width is a little greater than the length of the car, and whose length is at least 30 feet, is laid upon the bottom of the car so as to cover entirely all the metal parts. The infected articles are then laid loosely in place in a single layer and the long loose end of the linen strip is folded back over the infected articles. Another tray is now placed on the car and the linen is again placed both under and over the layer of goods to be disinfected, and this is repeated with each new tray until the car is loaded. In this way the wetting by the water that condenses on the metal parts is avoided, and the goods are protected from the drip from above, the fabrics are not marked by contact with the metal or soiled by colors that run. After the chamber is opened the articles are immediately taken out, stretched and shaken in the air a few times until they are dry.

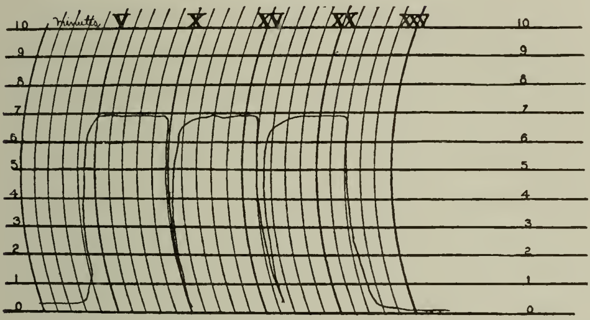
HOW TO OPERATE THE CHAMBERS.

For streaming steam, without pressure, warm the apparatus by allowing the steam to enter the jacket while loading the cars, which are rolled into the chamber and the doors closed, but not too tightly, for with this method a slight escape of steam about the doors is advantageous in procuring a good circulation inside the chamber. Wait until the contents of the chamber are thoroughly heated, in order to avoid condensation. As the air contained in the chamber becomes heated it expands, and one of the valves should be left open in order to allow as much of the air as possible to escape. Either the vacuum exhaust pipe or the drain from the bottom of the chamber may be used for this purpose. When the temperature of the contained air has reached 70° C. or over, the steam is turned into the interior of the disinfecting chamber by opening the valves in the circulating pipes which admit the steam from the jacket to the chamber. (See Fig. 16.) As the steam enters the top of the chamber the vacuum exhaust pipe must be closed and the drain from the bottom of the chamber must be wide open so that the descending column of steam may drive out the air. This bottom valve must be kept open throughout the steaming, which is ordinarily continued one hour after the temperature reaches 100° C. At first both valves of the two circulating pipes are opened in order to quickly fill the chamber with steam, but after about ten minutes these valves should be opened and closed alternately in order to obtain currents of steam first in one direction and then in the other, thereby washing the exposed articles with the steam. The steam is kept circulating in the jacket throughout the process. After the time of exposure has elapsed and the steam has been turned off from the interior of the chamber, the doors are opened, but the steam may be continued in the jacket in order to dry the contents of the cylinder. Fabrics, however, should be taken out immediately, stretched and shaken in the air until dry, which will prevent shrinking and creasing.

For steam under pressure, the apparatus is gradually warmed, as above, while the car is being loaded. The car is rolled into the chamber and the doors made tight. After the contents of the chamber are warmed, and the expanded air allowed to escape, all is made tight and the valve (J, Fig. 18) admitting high-pressure steam to the vacuum apparatus is opened wide. Next the valve G, which controls the vacuum-exhaust pipe, is opened, and the ejector is allowed to work until a vacuum of at least 15 inches is registered on the gage (12). It should not take more than a minute or two in order to exhaust this amount of air. Now steam is admitted from the jacket to the interior of the chamber by opening both valves C, C, of the circulating pipes. These valves should be opened wide so as to allow the steam to rush in and take the place of the rarefied air in all the interstices of the fabrics, etc. The pressure should not be permitted to rise above 20 pounds to the square inch. As a rule it is maintained at 15 pounds or one atmosphere, and is continued for twenty minutes after this pressure has been reached. From time to time the drip valve E should be opened so as to bleed the chamber of the condensed drip which collects at the bottom. When the time is up, the steam is blown off, either through the vacuum exhaust pipe or through the bottom drain, and when the pressure reaches normal, all is again made tight and the vacuum apparatus turned on, in order to exhaust as much of the steam and moist air contained in the chamber as possible. A vacuum of at least 15 inches is obtained, and by repeating this several times the wetting of the contents is largely avoided. During all this time the steam is continued in the jacket, for reasons already given. When the doors are opened, the contents of the chamber are either allowed to dry in the chamber, using it as a drying oven, with the steam in the jacket, or if the articles are fine clothing, expensive fabrics, hangings, and materials of that sort, they should be taken out immediately and each article shaken in the air and stretched by two persons, which will dry them rapidly and cause them to retain their shape without wrinkles or shrinkage.

In the municipal disinfecting stations of Paris the process of applying steam under pressure is as follows: The pressure is brought up to 15 pounds in the chamber, and held there five minutes, then released. The pressure is again brought up to 15 pounds, held there five minutes, and again released. This is repeated three times, when the disinfection is completed. The cylinders are fitted with an ingenious arrangement for the automatic registration of the process. Each chamber is connected by a small copper tube to a register with a moving pen and revolving drum carrying a chart. The horizontal lines 1 to 10 on the chart each represent a pressure of one-tenth of an atmosphere, and the vertical lines represent five minutes in the revolution of the drum. Each steaming is represented thus:

FIG. 27.*



These charts, which can be removed only by the chief of the station, are sent each day to the Inspector-General, and give a perfect guarantee that each steaming has been done as directed.

The Use of the Steam Chamber for Disinfection with Formaldehyd and Dry Heat in Partial Vacuum.

This is a very reliable and widely applicable method of disinfection. It has the advantage of being quick, of penetrating well, and of not being destructive. The method is particularly useful for the disinfection of clothing and baggage on a large scale. Great quantities of letter mail may in an hour be rendered safe from the danger of conveying non-spore-bearing infection, and that without puncturing the envelopes or injuring the letters in any way.

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* Redrawn from an unpublished report of Assistant Surgeon S. B. Grubbs, Marine Hospital Service.

The process requires a special apparatus, such as the Kinyoun-Francis disinfecting chamber, in which the following conditions may be obtained:

1. A temperature of 80° C.;
2. A vacuum of fifteen inches; and
3. A high percentage of formaldehyd gas.

The chamber must be loaded more carefully for this method than for steam disinfection, for the gas and dry heat lack the penetrating power of steam. Fabrics and other objects must be disposed so that all their surfaces are freely accessible to the action of the gas. It must be remembered that while the heat and the vacuum aid the disinfecting and penetrating power of the gas, the method cannot be trusted to disinfect mattresses, pillows, and other articles requiring deep penetration.

While the car is being loaded the steam is admitted to the jacket of the apparatus in order to gradually warm the disinfecting chamber. When ready, the car is rolled into place and the doors made tight. The steam in the jacket gradually heats the air in the chamber. By opening one of the blow-off valves some of the expanded air may thus be forced out.

When the temperature of the contained air in the cylinder reaches 80° C., all is made tight and the full head of steam is turned into the ejector until the gage shows that there is a vacuum of fifteen inches in the interior of the disinfecting cylinder.

The formaldehyd gas is now forced in. For this purpose it is generated from its watery solution, plus 20 per cent. of calcium chlorid, in an autoclave, under a pressure of 45 pounds to the square inch. Ten per cent. of glycerin may also be added to the formalin and calcium chlorid mixture, but this is not necessary.

Any of the retorts on the market for evolving formaldehyd gas under pressure may be used. The gas is conducted from the retort to the interior of the chamber through a small copper tube, similar in all respects to the method used in room disinfection. The copper retort or autoclave furnished with the steam chamber is too large to heat successfully the small amount of fluid required. It is therefore necessary to dilute the formalin solution with sufficient calcium chlorid or other neutral salt that is used, in order that the heating surface of the copper coils may be well covered. (See page 62.)

Use not less than 300 c.c. or about ten ounces of the formalin solution for each 1000 cubic feet of air space.

The solution is poured into the retort through the filling funnel (P, Fig. 18.) The steam is then allowed to course through the copper coil by opening the valves m and n. As the pressure in the retort begins to rise, the valve T is opened in order to allow the contained air to escape. When the pressure reaches 45 pounds, as registered upon the gage (8), the valve T is opened wide enough to allow the gas to enter the disinfecting chamber, but not wide enough to allow the pressure to fall below 45 pounds. It takes about ten minutes to disengage the gas from the small quantity of formalin used. After all the gas has been separated from its solution the valve T should then be opened wide so that some moisture may enter the disinfecting cylinder, which aids the power of the gas. The moisture may also be added by momentarily opening one of the valves in the circulating pipes, thereby allowing a little steam to enter the disinfecting chamber.

At the completion of the process the formaldehyd gas may be neutralized by heating water of ammonia in the iron retort (11, Fig. 18), using half the quantity of ammonia to the quantity of formalin solution. It is simpler and better, however, to open both doors of the chamber and allow the gas to blow away.

An exposure of one hour to these combined conditions of a high percentage of formaldehyd gas in a partial vacuum at a temperature of 80° C. is ample to thoroughly disinfect baggage, wearing apparel, household objects, letter mail, and objects generally, for non-spore-bearing infections.

CHAPTER II.

GASEOUS DISINFECTANTS.

General Considerations — Formaldehyd — Sulphur Dioxid— Hydrocyanic Acid—Chlorin—Oxygen—Ozone.

GENERAL CONSIDERATIONS.

A gas is the ideal weapon for destroying such an invisible foe as the infection of the communicable diseases, but the ideal gas for this purpose is still to be discovered. By reaching all portions of a room or confined space it lessens the risk of overlooking any surface upon which the infective agent may be lodged. Germicidal solutions are difficult to apply to all the surfaces of an ordinary living room, and it is furthermore difficult to hold the solution in contact with the ceiling, walls and other surfaces a sufficient length of time in order to obtain the certain action of the substance.

There is practically only one gas suitable for general application—viz., formaldehyd. This substance comes nearer being an ideal disinfectant than any of the gases so far exploited. It is not poisonous, does not injure fabrics, colors, metals, or objects of art and value. Formaldehyd has distinct limitations that are dealt with more in detail under the description of the gas.

Sulphur dioxid is too destructive to fabrics, colors, and metals for general use. It is very poisonous to all forms of animal life, which makes it particularly valuable in disinfection against insect- and animal-borne diseases. It has no equal for the disinfection of the holds of ships, cellars, sewers, and other rough structures infested with vermin.

The very poisonous and destructive nature of chlorin gas contracts its usefulness to narrow limits.

Hydrocyanic acid is too poisonous a gas to use in the household, and is limited in practice to the destruction of infection and vermin on board ships, in warehouses, greenhouses, granaries, and other uninhabited structures.

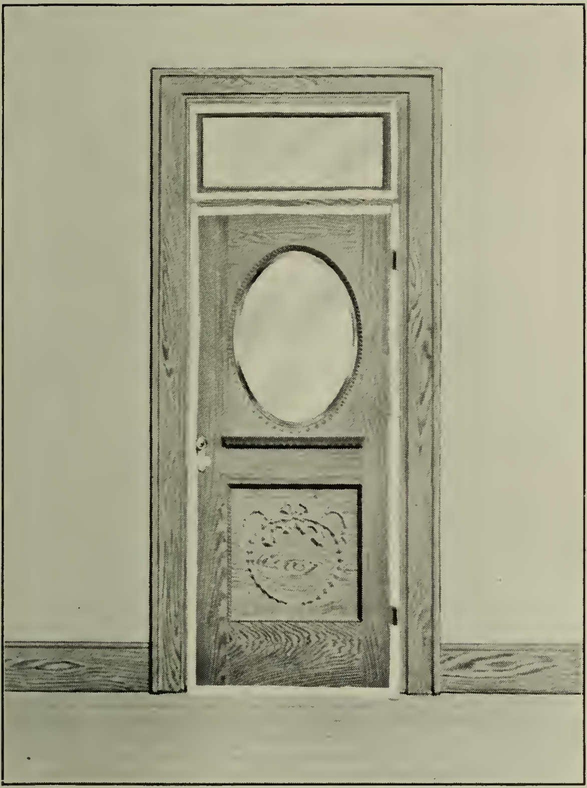
None of the gaseous agents can be depended upon for more than a surface disinfection. They lack the power of penetration.

The preparation of the room or space to be disinfected with a gas is a matter of great importance. A larger amount of the gas than is thought possible is lost through leaks and by diffusion, and therefore the room must be made tight. All cracks and crevices should be well closed by pasting paper over them or by calking with suitable material of some kind. Do not forget to close the registers, flues, hearths and ventilators, and look around for openings in out-of-the-way corners. Then expose the objects in the room so that the gas may have ready access to all the surfaces. Hang clothing, bedding and towels upon lines strung across the room; move bureaus, beds and furniture away from the walls; open doors of closets, drawers of bureaus, lids of boxes and the like, so that the gas may freely enter and diffuse to all corners.

While the articles in the room must be arranged so that the gas may freely gain access to all surfaces possible, the mistake must not be made of going to the opposite extreme of disarranging the contents of the room too much, for the same surfaces should be exposed to the gas that were exposed to the infection.

The strength of the gas and the time of exposure necessary

FIG. 28.



EXAMPLE OF SEALING DOORS, TRANSOMS, OR WINDOWS WITH GUMMED STRIPS OF PAPER.

to insure disinfection have been determined by exact laboratory experiments, but the conditions found in actual practice are so variable that we must allow for a liberal excess to make up for inevitable wastage.

If the room can be kept closed without serious inconvenience, the time of exposure may with advantage be prolonged to twenty-four hours. If the room is a leaky structure, an excess of the disinfectant will have to be used, and in estimating the cubic capacity of confined spaces the result should be rather an overestimate than an underestimate.

FORMALDEHYD GAS.

Formaldehyd gas is the most generally useful and one of the best disinfecting agents that we possess. Its superiority depends upon its high value as a germicide, its non-poisonous nature, and upon the fact that it is not destructive.

The secret of successful disinfection with this substance is to obtain a large volume of the gas in a short time. The ideal formaldehyd generator is still an unsolved problem.

The gas is a complex, unstable body, and failures in its use as a disinfecting agent result from an imperfect knowledge of its properties, its limitations, and its methods of production.

Formaldehyd (HCOH) exists in at least three well-recognized isomeric states:

1. Formaldehyd (formic aldehyd) is a gas at ordinary temperatures, colorless, and possessing slight odor, but having an extremely irritating effect upon the mucous membranes of the nose and conjunctiva. At a temperature of about —20° C. the gas polymerizes into paraformaldehyd, known commercially as paraform.

2. Paraform is a white substance, unctuous to the touch,

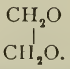
soluble in both water and alcohol. It consists chemically of two molecules of formaldehyd. It is this substance which is supposed to compose the commercial solutions of formaldehyd, known as formalin, formol, etc.

3. Trioxymethylene is formed by the union of three molecules of formaldehyd. It is a white powder giving off a strong odor of the gas. It is but slightly soluble in alcohol and water.

To sum up, formaldehyd exists in three states:

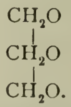
$CH_2O.$

Formaldehyd gas.



$$\begin{array}{c} CH_2O \\ | \\ CH_2O. \end{array}$$

Paraformaldehyd paraform.



$$\begin{array}{c} CH_2O \\ | \\ CH_2O \\ | \\ CH_2O. \end{array}$$

Trioxymethylene.

Formaldehyd gas possesses about the same specific gravity as air, which renders it poorly diffusible, although better than sulphur dioxid, and consequently it penetrates more readily to all portions and corners of a room. In disinfecting a leaky structure on a windy day it is only necessary to stand to the lee of the building to appreciate the great loss of gas that takes place through small cracks and crevices. It is, therefore, important to seal rooms well in disinfecting with formaldehyd gas. This is best done by pasting strips of paper around doors and windows and other cracks and crevices, or by calking (see page 85). In disinfecting a leaky room an excess of the gas is required to compensate for the loss.

Formaldehyd combines with nitrogenous organic matter; a few drops added to the white of an egg will prevent its coagulating by heat. The formaldehyd has combined with the albumin to form a totally new compound, the character of which has not been definitely determined. It is from this property of combining directly with the albuminoids forming the protoplasm of the micro-organisms that the gas is supposed to derive its powers as a germicide. It is perfectly plain, therefore, why there must be direct contact between the gas and the germ in order to accomplish disinfection. Formaldehyd also readily unites with the nitrogenous products of decay, fermentation, and decomposition, forming new chemical compounds which are both odorless and sterile. It is thus a true deodorizer in that it does not mask one odor by another still more powerful, but forms new chemical bodies which possess no odor.

Formaldehyd seems to have no detrimental effect upon silks, wools, cotton, or linen. It does not change colors, with the exception possibly of a slight effect upon some of the delicate anilin lavenders. An oil painting is not perceptibly altered after prolonged exposure to the gas.

While the watery solution, when heated, attacks steel and iron, the dry gas has no effect upon these metals. Neither the gas nor the solution attacks the other metals.

It is this non-destructive property of the gas that renders it generally applicable. It is practically the only disinfecting agent which may be used in the richest apartments, containing objects of art and value, without fear of injuring anything.

The commercial solutions known as formalin, formol, etc., are said to contain 40 per cent. of formaldehyd gas. They are not always up to the standard, and, being volatile, there is a certain loss if they are not well kept. In winter there is a decided deterioration owing to the polymerization and precipitation of the insoluble trioxymethylene. This substance is often found in abundance at the bottom of the bottle or carboy. For these reasons it is well to use an excess of the liquid in practical work if the exact strength of the formalin has not recently been determined.

Formalin solutions of commerce are almost all acid in reaction. This acidity is mostly due to formic acid. The commercial solutions also contain a certain amount of wood alcohol (about 10 per cent.), which is added to increase their solubility and stability. The solution is known commercially as a solution of the gas formaldehyd in water, but this is evidently not the case. The gas is condensed in order to dissolve it, and in solution it exists in one of its polymeric states, so that the solution known as formalin is probably mainly dissolved paraformaldehyd. This is one of the reasons why simply heating or evaporating the solution does not always result in driving off the gas, but sometimes simply evaporates the water and deposits the solid paraform, thereby defeating the object desired.

Temperature is an important factor in disinfecting with formaldehyd. The gas condenses at —20° C. to the solid polymeric paraform. Disinfection with this gas should never be attempted if the temperature is under 10° C. In cold weather the room to be disinfected should be heated by artificial means, otherwise some other disinfecting agent must be selected. The action of the gas seems to be about the same between the temperatures of 10° C. and 27° C. Higher degrees of heat materially aid the disinfecting power of the gas.

There is no such thing as chemically dry formaldehyd gas. Efforts to dry the gas result in its conversion to the solid polymeric state. A certain amount of moisture is therefore essential to obtain successful gaseous disinfection. The exact amount of moisture necessary has not yet been accurately determined, but it is probable that the full disinfecting power of formaldehyd gas is only obtained if the atmosphere contains 75 per cent. of moisture, and that only when the atmosphere is saturated with moisture is the maximum effect obtained. It is therefore advisable, in dry weather, to place a basin of boiling water in the room just before evolving the gas. Most of the apparatus in the market supply means of producing watery vapor with the gas.

Formaldehyd gas cannot be depended upon to accomplish more than a surface disinfection. Under ordinary circumstances it possesses small powers of penetration. It takes a large volume and a long exposure to penetrate fabrics. The meshes tend to polymerize the gas and deposit it as paraform upon the surface of the fabric. Large quantities of the formaldehyd are lost by uniting chemically with the organic matter of fabrics, especially woolens, which also hinders its penetration. Heavy fabrics, quilted goods, and other materials requiring deep penetration should not be disinfected with formaldehyd gas unless combined with heat in a special apparatus, as described below (page 110).

Formaldehyd gas has the power of killing spores, although not with sufficient certainty to render it a trustworthy disinfectant for the infections due to spore-bearing bacteria. It has the great advantage of killing dried organisms quite as well as moist ones.

Bacteria exposed directly to the action of a concentrated volume of the gas are destroyed almost instantly. Under similar conditions spores are sometimes killed within one hour. But in practical work it is necessary to prolong the time of exposure because the gas is evolved slowly from most of the forms of apparatus, and it takes considerable time for it to penetrate to all the corners and dead spaces of a room. Bacteria and their spores are not always directly exposed upon the surface of objects as they are in laboratory experiments, and, furthermore, they are frequently embedded in albuminous matter or in the dust, which retards the penetration of the gas and requires longer exposures. The time which experiment and experience have found necessary in using this gas as a disinfectant is stated under each method.

Formaldehyd gas is not toxic to the higher forms of animal life, although it stands at the head of the list of germicides. Long exposure to weak atmospheres of the gas, sufficient to kill germs, have but slight effect upon mammalian animals. Guinea-pigs, rats, mice, and rabbits, exposed to the most concentrated atmospheres obtainable by any of the methods for evolving it, are not killed after half an hour's exposure. The only effect produced is a violent irritation of the mucous membranes of the respiratory tract, from which the animals may subsequently die. Micro-organisms exposed to this same concentration of the gas are killed almost instantly.

Formaldehyd is not an insecticide. In the strongest volumes of the gas obtainable it seems to have practically no effect upon roaches, bedbugs, and the great majority of vermin of this class. It will kill mosquitos in the strengths and time prescribed for bacterial disinfection, provided there is direct contact between the gas and the mosquitos. The action of this substance upon mosquitos is discussed more in detail under formaldehyd as an insecticide.

Upon the completion of the time required to disinfect a room it is best to open all the doors and windows and simply let the gas blow away. This is often a troublesome procedure. If the windows can be reached from the outside, it is easy enough; but if the room must be entered, it is advisable for the operator to cover his mouth and nose with a moist towel, and he must act quickly. It was formerly the custom to neutralize the gas with ammonia, but this is little practised now. Half of the quantity of aqua ammonia may be driven into the room from an iron retort or autoclave, or the ammonia may simply be sprinkled about the room. It is true the ammonia neutralizes the formaldehyd by the production of formamid, but this substance has a persistent odor, greatly prolonging this unpleasant feature of formaldehyd disinfection.

The following methods are given as the most reliable for disinfecting with formaldehyd gas:

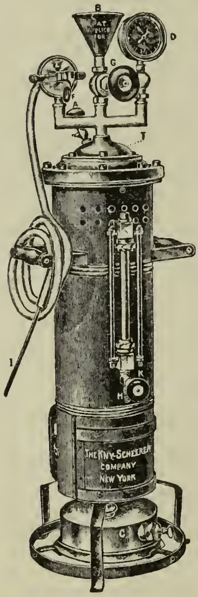
1. Autoclave under pressure.
2. Retort without pressure.
3. Generator or lamp.
4. Formaldehyd and dry heat in partial vacuum.
5. Spraying.
6. Heating paraform.

The Autoclave under Pressure.

The method of producing formaldehyd from its solution in an autoclave under pressure is highly efficient. A large volume of the gas is evolved in a very short time, and, owing to the force with which it is driven into an inclosure, better penetration and diffusion are obtained, and the disinfection is accomplished with more certainty than by the slower methods. The average room in a well-built house needs no special preparation, with this method, beyond the closing of doors and windows. The pasting and calking of the ordinary chinks and cracks is not necessary, provided the carpentry work is reasonably tight.

The autoclave consists of a retort sufficiently strong to withstand the required pressure. The retort is usually made of copper, as the formalin solution attacks iron. Or, if made of iron, the interior must be enameled with a suitable substance, as is done in some of the autoclaves on the market. The retort is furnished with a filling funnel, B (Fig. 29), a water gage, and a pressure gage D. The outlet pipe ends in a small copper tube, I, that may be introduced through the keyhole of a door. The retort is also usually provided with a safety valve, to prevent accidents. The heat is commonly applied by means of a Primus lamp, C, but a Bunsen gas jet or a gasoline flame will answer equally well.

FIG. 29.


B
PAT. APPLIED FOR
D
G
F
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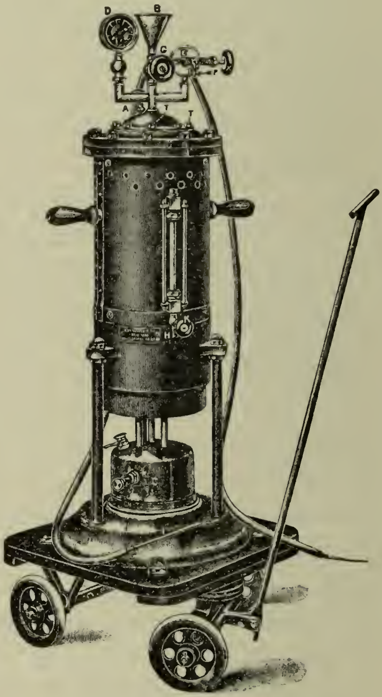
THE KNY-SCHEERER COMPANY NEW YORK
C

AUTOCLAVE FOR EVOLVING FORMALDEHYD GAS UNDER PRESSURE.

FIG. 30.

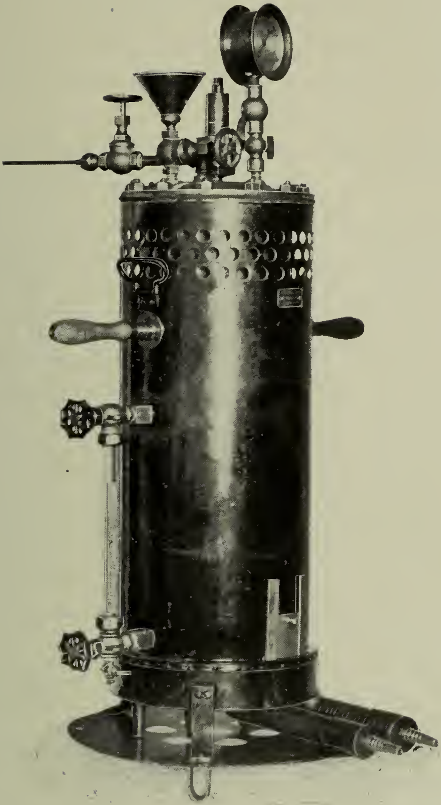


THE SAME—PORTABLE TYPE.

Too much reliance must not be placed upon the level of the water in the glass while using this apparatus under pressure, for in practice it is found to be untrustworthy.

The solution used in this apparatus consists of formalin

FIG. 31.



AN AUTOCLAVE FOR EVOLVING FORMALDEHYD GAS FROM ITS SOLUTION UNDER PRESSURE.

(40 per cent.), with the addition of 20 per cent. of calcium chlorid, or some other neutral salt, such as borax, or common salt. Ten per cent. of glycerin may also be added, but is not necessary. The neutral salt is added to the solution in order to prevent the polymerization of the formaldehyd, raise the boiling-point, and facilitate the evolution of the gas.

Use not less than 10 ounces of the solution for each 1000 cubic feet of space to be disinfected.

There must always be enough solution in the retort to show plainly in the water-glass. If a small room or inclosure is to be treated, it will be necessary to dilute the glyco-chloro-formalin with a sufficient quantity of the 20 per cent. calcium chlorid solution so that the bottom of the retort will be well covered with the liquid. Most of the autoclaves on the market are of such size that they will not work satisfactorily with less than 1 liter, or about 30 ounces of fluid.

Close all the valves tightly and bring the pressure up gradually. Be careful to open the outlet cock several times as the pressure rises, so as to drive out the contained air. After the pressure reaches 45 pounds the outlet valve may be opened and the gas permitted to enter the room or compartment to be disinfected. The gas may be evolved at a pressure higher than 45 pounds, but the pressure should not be allowed to drop below this point. It takes from 10 to 15 minutes to evolve the gas from 30 ounces of solution. After the gas has been separated from its solution, the valve should be opened wide, so that the pressure falls and the steam from the retort enters the compartment in order to furnish the moisture necessary for the formaldehyd gas to exert its maximum disinfecting power.

Practically all the gas is given off from this form of apparatus during the first part of the operation. It is therefore necessary to charge the retort separately for each room to be treated. The residue consists of a concentrated solution of calcium chlorid, and may be left in the apparatus in practising continuous disinfection. It will not do to fill the retort and use a portion of the gas for the disinfection of one room and the remaining portion for another room, for the second would get little or no formaldehyd gas.

Sometimes this form of apparatus squirts hot liquid from the outlet tube, and provision must therefore be made in room disinfection that nothing stand in the line of the entering tube that may be injured. Danger from this source may be obviated by hanging a towel a short distance in front of the tube, and another on the floor to catch the drip; or by placing a bucket so as to catch any fluid that may escape.

The disadvantages of this method are that it requires a rather heavy and somewhat cumbersome apparatus, and that it takes a skilled hand to operate it.

This method is applicable to rooms of any dimensions, it being only a question of the size and number of autoclaves. It may also be used for the disinfection of clothing and fabrics, suspended loosely in the room in such a manner that every article is freely accessible to the gas from all directions.

For the disinfection of a room presenting only smooth, hard surfaces, an exposure of one hour is sufficient to destroy all non-spore-bearing organisms. For fabrics, an exposure of twelve hours is necessary in order to insure penetration.

RETORT WITHOUT PRESSURE.

Formaldehyd gas may be evolved from its watery solution by simply distilling it in a retort without pressure. There are on the market several forms of apparatus based upon this principle.

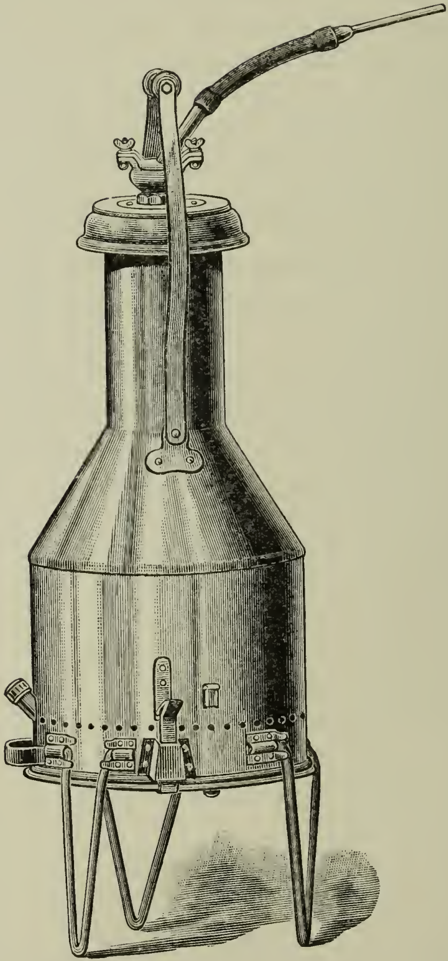
When formalin is boiled, the formaldehyd contained in the solution has a tendency to deposit in one of its polymeric forms instead of being driven off as a free gas. If formalin is boiled until it has evaporated to about half its bulk, it consists of a syrupy liquid which burns with a pale blue flame. This liquid is a concentrated solution of paraformaldehyd, and, if permitted to cool, separates out as a white, creamy solid, but if heated to the boiling-point the solution is broken up into the two molecules of which it consists and is disengaged as formaldehyd gas. As the solution condenses, the boiling-point rises, which favors the evolution of the gas.

It is therefore plain that upon first heating formalin the water is mainly evaporated, and subsequently the formaldehyd is disengaged. In other words, more of the disinfecting gas is evolved toward the end of the boiling than at first. In general practice this fact has an important practical bearing when using the retorts without pressure. It is necessary to place the required amount of solution in the apparatus and to use it all. It will not do to fill the retort and then use part of the gas and vapor evolved at first for the disinfection of one room, and continue with the residue to disinfect another room, for the first might not get its full share of the gas.

A retort well suited for evolving formaldehyd gas according to this principle is the Trenner-Lee apparatus shown in figures 32, 33. This apparatus consists of a copper retort with a very long neck and a series of compartments specially designed to prevent the boiling solution from bubbling over and squirting from the outlet tube. The retort proper is incased in a copper jacket, shown in the accompanying drawing, figure 33.

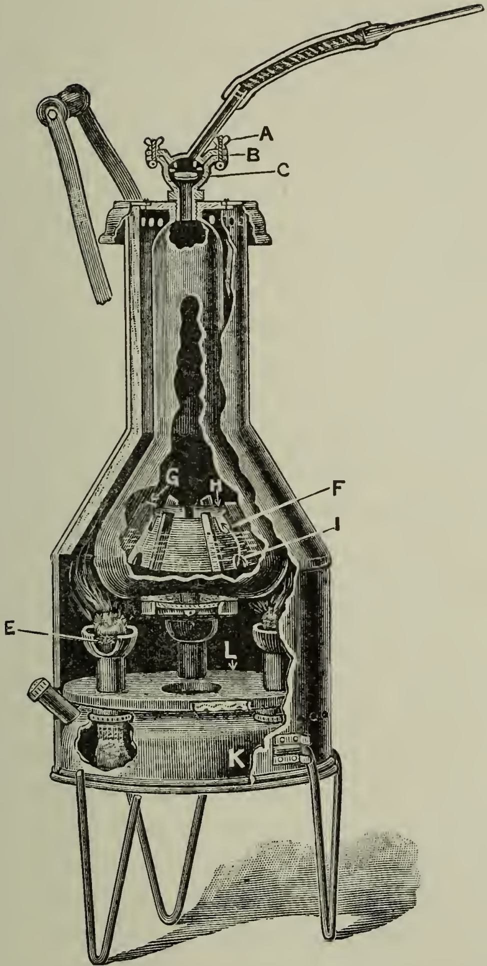
The heat is applied by means of the alcohol lamp K.

FIG. 32.



TRENNER-LEE RETORT FOR EVOLVING FORMALDEHYD GAS WITHOUT PRESSURE.

FIG. 33.



TRENNER-LEE RETORT, SHOWING COMPARTMENTS.

The burners E are so placed that only the periphery of the retort is in contact with the flame, and so arranged in relation to the retort that the maximum amount of heat is applied directly to one of the special compartments shown in the bottom. An asbestos pad is riveted to the bottom of the retort to serve the purpose of keeping the column of liquid in the center comparatively cool. A circulation of the formalin solution is thus obtained from the periphery toward the center. A disc L, made of non-conducting material, is placed where shown in the drawing, to keep the reservoir (K) of alcohol cool.

When the apparatus is working, the solution boils at the periphery of the retort, and as it ascends the sides of the long neck it comes in contact with the hot metal, which facilitates the evolution of the gas. While the gas is being disengaged the little plate of metal shown at C is agitated, and by its tinkling indicates when the process begins and ends.

The commercial solutions of formalin are used in this apparatus. The addition of 1 per cent. of glycerin is claimed to add to its efficiency when evolved in this way. The glycerin is added because it raises the boiling-point and retards polymerization of the formaldehyd in solution. It deposits as an imperceptible film upon the surfaces of exposed objects. This film is supposed to favor the disinfecting power of the gas by holding it in direct contact with the bacteria.

Use not less than 10 ounces of formalin (40 per cent.) for each 1000 cubic feet of air space, and keep the room closed no less than six hours, if only smooth, hard surfaces are to be disinfected; but an exposure of twenty-four hours is desirable to disinfect fabrics, or rooms of peculiar construction requiring time to penetrate.

In disinfecting rooms and spaces with this apparatus it is necessary to tightly close all cracks, crevices, and the like, by the usual means. Doors and windows of reasonably tight construction need not be pasted.

It requires about fifteen minutes to distil 10 ounces of the solution from this apparatus. The gas escapes in a moist state, and it is therefore not necessary to add moisture. The gas and watery vapor escape from the retort with considerable force, which aids diffusion and penetration. The method is therefore efficient for general application in disinfecting wherever formaldehyd gas is indicated, particularly in rooms and spaces not over 5000 cubic feet in capacity.

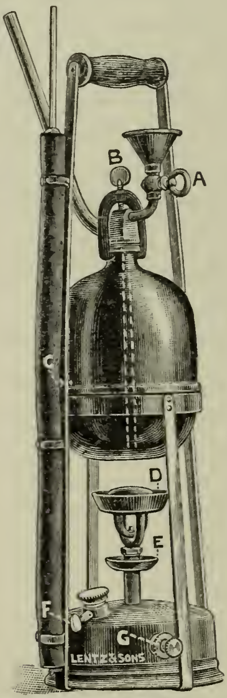
The Lentz formaldehyd gas generator is constructed upon principles similar to the above, and is an efficient, simple and cheap apparatus for the evolution of formaldehyd gas from its watery solution.

The apparatus consists simply of a copper retort, holding four pints, in which the formalin is distilled. The heat is supplied by means of a Primus burner, which develops a high temperature and boils the solution energetically and therefore vaporizes the liquid quickly, driving off the gas with considerable force. The retort is furnished with a filling funnel A (Fig. 34), from which a metal tube extends downward nearly to the bottom of the retort, serving the same purpose as the drain-traps used in plumbing. The solution automatically closes the funnel tube as long as there is sufficient of it in the retort; but when the liquid has evaporated so that it is lower than the aperture at the bottom of the funnel tube, the vapor may be seen to escape from A, or the gas may readily be detected by its irritating odor.

The stop-cock A is therefore left open while the solution boils and the gas is being disengaged. As soon as the gas escapes from the filling funnel, the stop-cock A is closed and the flame extinguished; or if the room to be disinfected is a large one, more solution may be poured into the retort and the process continued.

The stopper B of the retort is of special design and the outlet tube is inclined upward in order to diminish the risk of throwing liquid into the room, as there is considerable foaming during ebullition, caused largely by the glycerin which is added to the solution of formaldehyd. It is claimed that the addition of 1 per cent. of glycerin aids the disin-

Fig. 34.



The Lentz Formaldehyd Gas Generator.

fecting power of the gas by forming a film upon the surface, which holds the formaldehyd gas in contact with the bacteria. The glycerin also raises the boiling-point of the solution and retards the polymerization of the formaldehyd in solution, thereby facilitating the evolution of the gas.

In disinfecting with this apparatus use not less than 10 ounces of formalin (40 per cent. formaldehyd) for each 1000 cubic feet of air space. One per cent. of glycerin may be added to the formalin. Keep the room closed six hours where only smooth, hard surfaces are to be disinfected, but twelve hours for textiles or spaces of peculiar construction requiring time for penetration.

The preparation of the room, the amount of formalin to be used, the time of exposure and other details are similar to those given for the use of the Trenner-Lee apparatus (see above).

GENERATOR OR LAMP. The formaldehyd gas is generated from the lamp by the dehydrogenation of the vapor of wood alcohol, in passing it, mixed with air, over incandescent platinum.

The following reaction takes place:

$$\underset{\text{Methyl alcohol.}}{CH_3OH} + \underset{\text{Oxygen.}}{O} = \underset{\text{Formaldehyd.}}{HCOH} + \underset{\text{Water.}}{H_2O}$$

The platinum is in a state of fine division on asbestos discs in this form of apparatus. The disc is platinized by saturating the asbestos with a solution of platinic chlorid in alcohol. The alcohol is then burned off and the disc heated to incandescence, which leaves the metallic platinum on the asbestos.

The chemical action resulting from the dehydrogenation of the methyl alcohol produces sufficient heat to keep the platinum incandescent, so that the process continues automatically after it has been started.

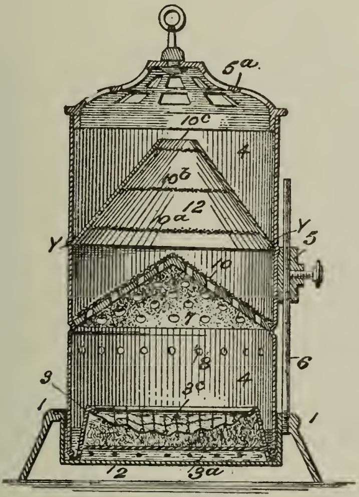
There are several difficulties met with in a generator built upon this principle, which must be overcome in order to have a practical lamp. It is of prime importance that almost all of the vapor of the wood alcohol be changed to formaldehyd gas. If much of the vapor of wood alcohol escapes into the air unaltered it is liable to take fire and result in serious consequences. In none of the generators so far devised is the amount of formaldehyd theoretically possible, obtained from the alcohol consumed. It is also important to prevent the heat from the incandescent platinum flashing back and setting fire to the reservoir of alcohol which is used to feed the apparatus.

In the Kuhn formaldehyd lamp these difficulties are well met by passing the vapor of the wood alcohol between two cones of platinized asbestos. One of these cones is not platinized upon its under surface, and by its position acts as a deflector, preventing the heat being thrown directly upon the surface of the pan *3*, figure 35, containing the wood alcohol. This pan is filled with mineral wool that serves the purpose of a wick.

The series of small openings shown at *8* in the accompanying illustration admit the air and are gaged to supply just sufficient quantity for the dehydrogenation of the alcoholic vapor. The water surrounding this pan acts as a seal, preventing air entering the lamp and mixing with the alcohol vapor, except as intended through the series of small openings shown at *8*. In addition, the water is slowly volatilized by the heat produced during the process, hydrating the formaldehyd gas evolved, which experiments have shown increases its germicidal power. Any alcoholic vapor which escapes the action of the platinized cones is then subjected to successive passages through five layers of 20-mesh copper wire shown at *10a*, *10b* and *10c*, in the accompanying cut, serving the purpose of converting some of it into formaldehyd gas.

One of the special advantages claimed for generators of this kind is that nascent formaldehyd is liberated, and it is a well-known fact in chemistry that reagents exert their most powerful effect when in this state. The manner of evolving the gas is also free from the objection of some of the other processes in that there is less polymerization of the formaldehyd gas to paraform. Hence, when the room is aired after the completion of the process, the unpleasant and irritating effects of the gas do not cling so persistently as in some of the other methods.

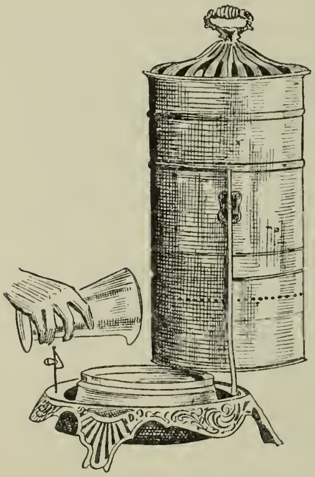
Fig. 35.



Kuhn Formaldehyd Generator or Lamp.

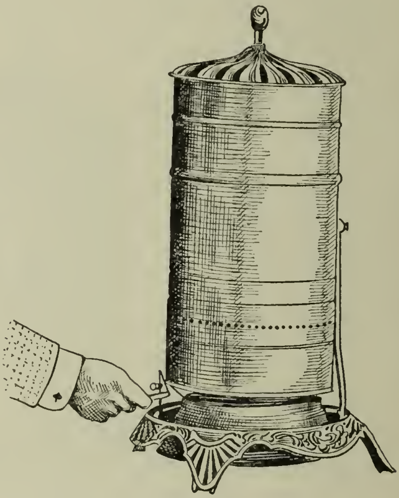
One of the disadvantages of the lamp is that the gas is generated very slowly. It takes about two hours to convert three pints of wood alcohol, which is the amount required to disinfect 2000 cubic feet of air space. When the gas is evolved so slowly it takes a long time for it to permeate into all the nooks and corners of a room. It therefore lacks the penetrating power of the quicker processes.

FIG. 36.



FORMALDEHYD GENERATOR. FILLING THE LAMP.

FIG. 37.



FORMALDEHYD GENERATOR. LIGHTING THE ALCOHOL.

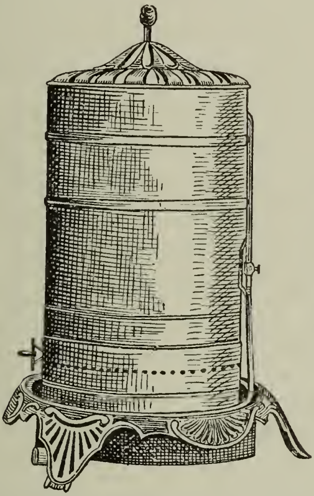
In using this method for the disinfection of rooms it is very important to tightly seal, calk, or otherwise close all cracks and crevices, else the gas may be lost almost as quickly as it is generated, thereby defeating the object to be attained.

There is also a certain objection to leaving a lamp locked in a room with the possibility of fire, however slight, especially as there is no way of telling what is going on, except by opening the room and thereby spoiling the operation.

To use the apparatus, unlatch and slightly raise the cylinder, swing it around on the upright rod, as shown in figure 36.

Then pour into the pan not less than 1 quart of standard wood or methyl alcohol (95 per cent.). The alcohol saturates the mineral wool which acts as a wick. Next fill the space around the pan with about 3 pints of water, so that the level of the water is within half an inch of the top of the pan. When this is done, swing the cylinder back over the pan, as shown in figure 37, leaving an open space of about an inch between the wick and the cylinder. Now light the alcohol and permit it to burn one minute and a half,

FIG. 38.



FORMALDEHYD GENERATOR IN OPERATION.

so as to thoroughly heat the platinized discs. Then extinguish the flame by means of an extinguisher of asbestos, which is laid over the pan and kept in close contact until it is certain that the flame is extinguished. The operator must assure himself on this point or the lamp will not generate formaldehyd gas. In the absence of one of the asbestos extinguishers a flat metal sheet or a pane of glass may be used.

After the flame is extinguished lower the cylinder into the water and fasten the latch at the bottom, as shown in figure 38. The lamp should now begin to throw off formaldehyd gas. Before leaving it the operator must satisfy himself that the cylinder is very hot, that the flame is no longer burning, that the cylinder is well under the surface of the water, and that there is a distinct odor of gas evolved.

The generator or lamp may be used for the surface disinfection of rooms not over 2000 cubic feet and of tight construction. Use not less than 25 ounces of wood alcohol for each 1000 cubic feet of air space, and prolong the exposure to not less than twelve hours, preferably twenty-four. It is necessary to tightly calk, seal, or close all cracks and crevices in order to prevent the loss of the gas.

At the completion of the process there should be a distinct odor of formaldehyd gas, all the wood alcohol should be consumed, and about one-third of the water in the pan evaporated.

FORMALDEHYD AND DRY HEAT IN PARTIAL VACUUM.

This is a very reliable and widely applicable method of disinfection. It has the advantages of being rapid, of penetrating deeply, and of not being destructive. The method is particularly useful for the disinfection of clothing and baggage on a large scale. Great quantities of letter mail may be rendered safe in an hour by this process, and that without puncturing the envelopes or injuring the letters in any way.

The process requires a special apparatus in which a high percentage of formaldehyd gas, a temperature of 80° C., and a vacuum of 15 inches may be produced. These requirements are well met in the Kinyoun-Francis disinfecting chamber figured and described on page 56.

The articles to be disinfected are placed on the rack or car which is rolled into the chamber. The door is closed and secured. The clothing and baggage must be disposed loosely in the cylinder so as to be well exposed to the action of the gas and heat. The steam is now allowed to enter the jacket of the apparatus, and as the air of the disinfecting cylinder is heated it expands. By opening one of the blow-off valves some of the contained air may thus be forced out. When the temperature inside the cylinder reaches 80° C., the steam is turned into the ejector until the gage shows that there is a vacuum of 15 inches in the interior of the disinfecting cylinder. The formaldehyd is now forced in. For this purpose the formaldehyd is generated from its watery solution plus 20 per cent. of calcium chlorid, in an autoclave under a pressure of three atmospheres, according to the method described on page 93. Use not less than 10 ounces of a 40 per cent. formalin solution for every 1000 cubic feet. Steam is kept slowly coursing through the jacket in order to maintain a constant temperature of 80° C. or more throughout the operation. The vacuum usually falls a few inches, depending upon the quantity of the gas entering the chamber.

An exposure of one hour to these combined conditions of a high percentage of formaldehyd gas, in a partial vacuum, and under a temperature of 80° C. is ample to thoroughly disinfect baggage, wearing apparel, mail and household objects generally.

This method should not be used for the disinfection of pillows, mattresses and similar articles requiring deep penetration.

In the disinfection of letter mail by this process it is only necessary to arrange the letters loosely on end upon wire trays or open frames. The partial vacuum aids the penetration of the gas and heat, so that it is not necessary to puncture the envelope. It is of some importance to take out all letters sealed with wax, as this substance melts at the temperature used.

For a complete description of this valuable method of disinfection, see page 79.

SPRAYING.

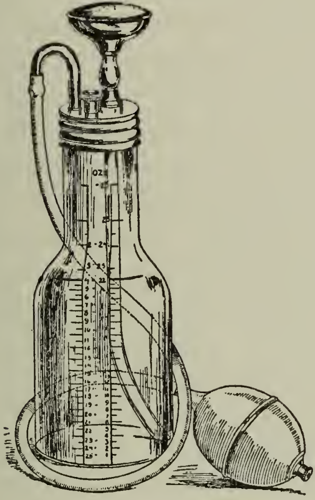
Spraying is a very useful method of applying formaldehyd as a disinfectant, especially as it may be carried out without special apparatus. It has distinct limitations, and unless all the necessary conditions are carefully observed, spraying is a very untrustworthy method.

The formalin may be sprayed upon sheets hung up in a confined space, or it may be sprayed directly upon the object to be disinfected. In the latter case the object gradually becomes bathed in an atmosphere of the gas which is slowly evolved by the evaporation of the liquid, and it also receives the benefit from the direct contact with the germicidal solution.

From its watery solution at ordinary temperatures formaldehyd gas is given off very slowly, and in very uncertain quantity. It also diffuses poorly into dead spaces by this method. It is not applicable to large inclosures, nor to rooms having many drawers, nooks, or spaces where the gas would have difficulty in permeating. The amount of the gas evolved from any given quantity of sprayed solution is very variable, depending upon many conditions, such as temperature, pressure, purity of the solution, surface exposed, and other less known factors.

In cold weather the formalin is apt to polymerize, and the water will evaporate from the solution sprayed upon a surface, leaving most of the formaldehyd as a white, solid residue of paraform. Hence the method should never be used except in warm weather or in rooms artificially heated. Warmth not only facilitates the evaporation of the fluid, but aids the disinfecting power of the gas.

FIG. 39.



FORMALDEHYD SPRINKLER.

The formalin should be sprayed in very small drops, which exposes a maximum surface for evaporation. Large splashes of the solution, applied by means of brushes, mops, and the like, are less reliable.

A convenient form of spraying apparatus used by the Chicago Board of Health is shown in Fig. 39. In using this method for the disinfection of rooms, spray not less than 10 ounces of formalin (containing 40 per cent. formaldehyd) for each 1000 cubic feet, upon sheets suspended on lines across the room. Used in this way a sheet 5 by 7 feet will hold about 5 ounces without dripping or the drops running together.

The room must be very tightly sealed and kept closed at least twenty-four hours. The method is limited to rooms or apartments not exceeding 2000 cubic feet, because the gas is evolved so slowly that there is more loss than can be replaced by the slow evaporation, and the gas will not permeate into the corners of large rooms in sufficient volume to insure its disinfecting action.

It requires some practice to apply the sprinkling method effectually. The gas is irritating, and it must be done quickly and at the same time carefully, so that the liquid remains on the sheets in small and discrete drops.

The sheets may be wrung out in the formaldehyd solution and then hung up in the room; but while this method is simpler, it cannot be recommended as being as trustworthy as spraying.

In the disinfection of rooms with formaldehyd gas by any of the methods it is useful to supplement the action of the gas, as evolved from the generators or regenerators, by spraying. A pure formalin solution should be used to sprinkle the carpet, rugs, upholstered furniture, hangings, and other objects requiring deeper penetration, just before the room is finally closed, and the gas produced by whatever method is used.

The disinfection of small objects, such as a few handkerchiefs, laces, or some letters, objects of art, or articles of value, may be done successfully by sprinkling them liberally with formalin and placing them in a tight box or drawer, in a warm place, for twenty-four hours. As the formalin solutions are generally acid and there is some risk of spotting objects of great delicacy and value, these may be disinfected by arranging them in a small box which can be thoroughly sprinkled without wetting the objects themselves. The box should be tightly closed and kept in a warm place for the required time.

The mail may also be effectively disinfected by a modification of the spraying method. The corner of the envelope is clipped off and a few drops of formalin are introduced by means of an eye dropper. Several drops are then placed on the outside surfaces of the envelope and the letters are put in a tight box or bag and laid in a warm place for six hours, preferably over night. In the absence of better apparatus very large quantities of letter mail may thus in a short time be disinfected by this process by one or two persons. In disinfecting large quantities it is best to clip the edge of the envelope with scissors, insert the few drops of formalin, and then place the letters loosely in a leather or closely woven mail sack. They should not be tied in bundles. Upon each layer of letters in the sack sprinkle some formalin, continuing this until the sack is partly filled, when it must be closed tightly and may be sent in this condition to its destination, provided the journey is of at least six hours. Of course, the mail sacks should be kept in a warm place and should be well sprinkled with formalin before the letters are placed in them. When the sack is opened, the smell of the gas is very strong. It is therefore advisable to have them opened out of doors. Here the sprinkling of a little ammonia may be done with advantage.

For the disinfection of baggage packed away in a trunk or container the spraying method is not a reliable one for general use. Sprinkling formalin on baggage in a trunk or box may be depended upon to kill non-spore-bearing organisms, such as typhoid, diphtheria, plague, cholera, etc., through three layers of blankets. The method, however, is not reliable unless a sufficient quantity of the solution is sprinkled in small drops uniformly over the surface and between many layers. The evaporation of the solution under these circumstances is slow and uncertain. The container should be kept in a warm place to facilitate the evolution of the gas and to increase its disinfecting power.

Use not less than 4 c.c. of formalin, containing 40 per cent. of formaldehyd, over every square foot of surface and between every three layers of blankets, or their equivalent. Somewhat less will suffice for linen and cotton goods. This means the use of about 50 c.c. of the solution for each cubic foot. Twenty-four hours' exposure under these circumstances is sufficient to insure successful disinfection. Increasing the time over twenty-four hours neither increases the penetrating action nor adds to the power of the disinfectant.

Pouring the liquid in one place or splashing the liquid with brushes will not suffice. The formalin must be carefully sprinkled in small drops and distributed evenly over the surface, and between many layers.

Excessive moisture of the fabrics interferes with penetration and gives irregular results. Pure formalin spots leather and injures certain delicate dyes. Even pure water will spot some silks and colors. Care must therefore be exercised as to the articles with which the formalin comes in contact.

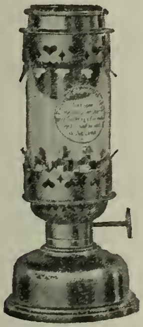
HEATING PARAFORM.

Paraform is a white substance, unctuous to the touch and soluble in water and alcohol. It is one of the polymeric forms of formaldehyd. When heated, paraform first melts and then breaks up into the two molecules of formaldehyd of which it consists, evolving that gas.

Paraform will burn with a low, blue flame. The resulting products of combustion contain no formaldehyd gas. In using this method to disinfect, it is therefore essential to heat the paraform to the point required to evolve the gas, but below the point of ignition.

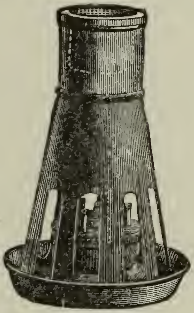
Paraform may be purchased either in the form of a powder or compressed into pastils. Much of the substance sold under the name paraform probably also contains trioxymethylene, which is insoluble and disintegrates into its three constituent molecules with more difficulty than paraform.

FIG. 40.



FORMALIN LAMP.

FIG. 41.



FORMALIN DISINFECTOR.

The lamps devised for evolving the gas according to this principle have the advantage of being exceedingly simple and comparatively cheap. The disadvantages of the method are that the gas is given off without moisture and tends to polymerize readily, especially on cool, dry days. The gas is also given off rather slowly and with little force, so that it permeates poorly to all the nooks and corners of a room.

The Schering lamp and formalin disinfector consists simply of a metal pan in which the paraform is heated by an ordinary spirit lamp. The wicks must not project more than a twelfth of an inch, which is enough to give a flame that will heat the pan and its contents sufficiently to cause volatilization of the paraform without danger of combustion. Should the paraform ignite, no formaldehyd gas will be produced and the object of the disinfection will be defeated.

This method of evolving formaldehyd gas is useful for the surface disinfection of closets and small inclosures, containing less than 1000 cubic feet. The space must be of tight construction, and all cracks and crevices must be carefully sealed. The exposure should not be less than twelve hours, and preferably twenty-four hours. Use not less than two ounces of the substance for each 1000 cubic feet of air space.

SULPHUR DIOXID.

Sulphur dioxid (SO_2) is an efficient surface disinfectant. It is very destructive to animal as well as to vegetable life, and it is this property that makes it of special value in destroying contagion that is spread through the agency of vermin, such as rats, mice, flies, fleas, mosquitos, etc. In this regard it has no superior. Its action as a disinfectant demands the presence of moisture. It cannot be depended upon where penetration is required. It does not kill spores. It is therefore inapplicable to the prevention of the spread of such infections as anthrax, tetanus, or malignant edema; or for the disinfection of bedding, mattresses, pillows, blankets, fabrics, and similar articles needing more than a mere surface purification.

Sulphur dioxid possesses the advantage of being efficient, cheap, and readily procurable. There is hardly a cross-road store in the country where a reasonable quantity of sulphur, either in the form of flowers or in rolls or sticks, under the name of brimstone, cannot be obtained. The small amount required to disinfect large cubic areas renders the process comparatively cheap, and specially applicable to the holds of ships, freight cars, granaries, stables, outhouses, and similar large rough structures—particularly if infested with vermin.

The disadvantages of sulphur dioxid as a disinfecting agent are such as to contract its application to rather narrow limits. It bleaches all coloring matter of vegetable origin and many anilin dyes, and attacks almost all the metals. It acts upon cotton and linen fabrics so as to seriously weaken their tensile strength.

Sulphur dioxid is a heavy, colorless, irrespirable gas, with a peculiar suffocating odor and irritating properties. It has a density of 2.4; a liter weighs 2.86 grams; 100 cubic inches weigh 68.89 grams. On account of the heavy specific gravity of sulphur dioxid as compared to air, it diffuses slowly, which partly accounts for its inferior penetrating power as a disinfectant.

Cold water takes up more than thirty times its volume of sulphur dioxid. The solution contains hydrogen sulphite or sulphurous acid (H_2SO_3), and it is in reality this acid that is the disinfecting agent. Dry or anhydrous sulphur dioxid was found by Geddings to be practically inert so far as its effect upon micro-organisms is concerned. He found that an atmosphere containing as much as 10 per cent. of the dry sulphur dioxid has no effect upon anthrax, cholera, the colon bacillus, typhoid, diphtheria, or the Bacillus icteroides of Sanarelli, after forty-eight hours' exposure; while an atmosphere containing only 0.6 per cent. of the gas plus moisture showed active germicidal effects upon non-spore-bearing organisms after twenty-four hours' contact; 1.6 per cent.

was equally effective in eighteen hours, and 4.25 per cent. in sixteen hours.

The watery solution of sulphur dioxid consisting of sulphurous acid remains unchanged so long as air is excluded, but when exposed to the oxygen of the air, it is converted into sulphuric acid (H_2SO_4), and it is these two acids that have such a destructive effect upon the fiber and colors of fabrics. Cotton and linen that have been exposed to sulphur dioxid in the presence of moisture become so weakened that they tear readily. Sulphur fumigation is therefore not applicable to such materials.

Sulphur dioxid may readily be condensed into a clear liquid by either cold or pressure, or a combination of both. At ordinary atmospheric pressure it condenses if the temperature is reduced to —18° C., which is about the temperature of a mixture of ice and salt. At ordinary temperature it liquefies if the pressure is raised to about four atmospheres—*i. e.*, 60 pounds.

This liquid is a stable substance when kept well sealed and protected from the action of the air. It rapidly volatilizes by pouring it into an open vessel. It is now found in commerce and is a good method of producing the gas for disinfecting purposes.

The sulphurous and sulphuric acids which are produced by sulphur dioxid in the presence of moisture and oxygen attack almost all the ordinary metals. Therefore metal objects should be removed from the room that is to be disinfected. If they are fixtures, they may be protected by greasing them with vaselin.

The complete combustion of one pound of sulphur in a space of 1000 cubic feet will produce 1.15 per cent. of sulphur dioxid. But this amount cannot be obtained in practice because the sulphur of commerce contains impurities, such as sulphate of lime and sand, and a portion is always oxidized to the formation of ill-defined compounds. Therefore 1 pound may be considered as producing approximately 1 per cent. of the gas by being burned in 1000 cubic feet of space, and 5 pounds will produce about 5 per cent. This is the amount found by experiment to be sufficient to kill all the non-spore-bearing organisms after sixteen hours' exposure.

The amount of moisture necessary to convert the sulphur dioxid into sulphurous acid is readily computed. It will be found that $\frac{1}{5}$ of a pound, theoretically, of water should be volatilized or added for each pound of sulphur burned. The water may be added in the form of steam, or it may be added after the combustion of the sulphur, in the form of a finely divided spray; or it may be vaporized by the heat generated by the combustion of the sulphur itself. The latter method is the one that will commend itself in practical use and is described under the pot method.

In disinfecting with sulphur dioxid it is necessary to tightly seal the room. The gas is disengaged so slowly that much of it will escape through small openings, especially near the floor. All the cracks and keyholes must be stuffed with a suitable material or pasted with paper. Paper should be pasted about all the windows and doors. Of course, radiators, ventilators, and fireplaces must be closed by means that will readily present themselves. In cold weather the heating of the rooms by any means at hand will greatly aid the disinfecting action of the gas.

Sulphur dioxid is very fatal to animal life. It quickly kills rats, mice, rabbits, guinea-pigs, cats, roaches, fleas, mosquitos, and all kinds of insects. It is therefore a valuable means of ridding a confined space of all sorts of vermin. It is invaluable for this purpose in the disinfection of granaries, ships, and structures for plague, as well as rooms and wards for yellow fever and malaria.

There are three well-recognized methods of fumigating with sulphur dioxid, viz.:

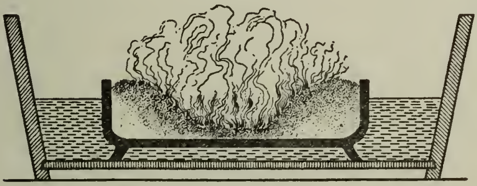
1. The pot method.
2. Liquid sulphur dioxid.
3. The sulphur furnace.

THE POT METHOD.

The pot method is at once the easiest, cheapest, and probably the most efficient method of disinfecting with sulphur dioxid. The only materials required are iron pots and some sulphur. The best way to apply the method is by placing the sulphur in large, flat, iron pots, known as Dutch ovens. Not more than 30 pounds of sulphur should be placed in each pot. The sulphur is preferably used in the form known as flowers of sulphur. If it is in sticks or rolls it should be crushed into a powder, which may conveniently be done by placing the sulphur in a stout box and pounding the lumps with a heavy timber. The pot holding the sulphur should be placed in a tub of water, as shown in the sketch. The water not only diminishes the danger from fire, but by its evaporation furnishes the moisture necessary to hydrate the sulphur dioxid upon which the disinfecting power of the gas depends. The great advantage of this method is that the moisture is furnished automatically and it does away with the necessity for its introduction by means of steam or spray. Although the specific gravity of sulphur dioxid is heavier than that of air, when hot it rises aided by the upward current produced by the burning sulphur. Therefore the pots should not be on the floor, or bottom of the hold in case of vessels, for fear of the cold gas settling, and by depriving the flame of oxygen cause it to become extinguished before all the sulphur is burned. In rooms and freight cars, the pots are best placed upon a table or box, and in the holds of ships upon piles of ballast, or on the "'tween decks."

The sulphur may be lighted by means of hot coals or a wood fire, or any other convenient means. But the most reliable way to get it well lighted is by alcohol. Make a little crater in the sulphur, as shown in the accompanying diagram, saturate liberally with alcohol, and light. The sulphur then burns in the center, and, as it melts, runs down from the sides to form a little lake at the bottom of the crater. If the sulphur is heaped up in a mound in the pot the flame is apt to go out.

FIG. 42.



THE POT METHOD OF BURNING SULPHUR.

Upon the principle of not putting all our eggs into one basket, it is best to have a number of pots. Each pot should not contain more than 30 pounds of sulphur, and the pots should be well distributed in various portions of the space to be disinfected. Use 5 pounds of the sulphur for each 1000 cubic feet of space. Four pounds are theoretically sufficient to produce four per cent. of sulphur dioxid, but the extra pound is for the inevitable wastage. Some of the sulphur always remains unconsumed, and there is always considerable loss by leakage and absorption of the gas.

The time required for sulphur dioxid to act varies with the purpose for which it is used. For the destruction of vermin or animal life two hours' exposure is ample. For the destruction of bacterial infection sixteen to twenty-four hours' exposure is necessary.

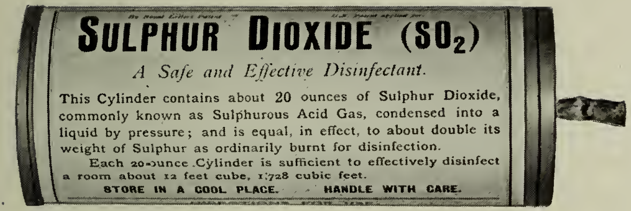
Liquid Sulphur Dioxid.

Liquid sulphur dioxid, commonly known as sulphurous acid gas, though an efficient method of applying sulphur dioxid to the disinfection of large spaces, is about ten times as expensive as burning sulphur by the pot method. It has the advantage of liberating a large volume of the gas rapidly, thereby diffusing the gas more quickly to all parts of a room than is possible with the slower methods of combustion of the sulphur either by the pot method or by the furnace. This is a great advantage in a gaseous disinfectant, because by the slower method of production the gas not only diffuses slowly and imperfectly into dead spaces, but much is lost through the cracks and pores, some of the gas is dissolved by the water and moisture that may be present, and lost in other ways, so that there is a gradual diminution of its amount. On account of this loss the desired percentage may not be obtained in the slower methods of its evolution. The use of liquefied sulphur dioxid also has the advantage of avoiding the danger of accidental fire.

One pound of sulphur (atomic weight, 32) will produce about 2 pounds of sulphur dioxid (atomic weight, $S32 + O_232 = 64$); therefore twice as much by weight of the liquid sulphur dioxid is necessary in practical disinfection; that is, instead of using 5 pounds of sulphur, it is necessary to use 10 pounds of the liquefied gas per 1000 cubic feet.

The method of using the liquid sulphur dioxid is very

FIG. 43.



SULPHUR DIOXIDE (SO_2)

A Safe and Effective Disinfectant.

This Cylinder contains about 20 ounces of Sulphur Dioxide, commonly known as Sulphurous Acid Gas, condensed into a liquid by pressure; and is equal, in effect, to about double its weight of Sulphur as ordinarily burnt for disinfection.

Each 20-ounce Cylinder is sufficient to effectively disinfect a room about 12 feet cube, 1,728 cubic feet.

STORE IN A COOL PLACE. HANDLE WITH CARE.

A

A. LIQUEFIED SULPHUR DIOXID IN TIN CANS.

B

B. SULPHUR DIOXID IN SIPHON.

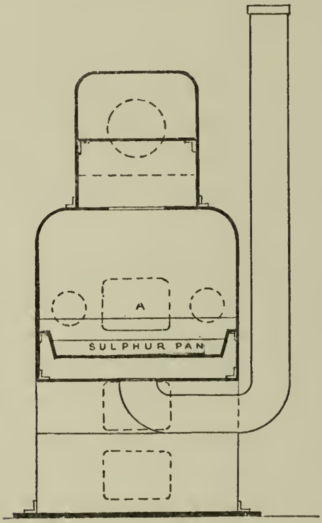
simple. If the substance is used in the small tins, it is only necessary to cut simultaneously the leaden pipes in the tops of the necessary number of cans, and invert the latter in an ordinary washbowl or iron pot, when volatilization rapidly occurs. The operator must act quickly and be prepared immediately to leave the room and shut the door. If the substance is contained in glass or metallic siphons, the necessary amount of liquid sulphur dioxid can be projected from the outside through a small pipe passed through the keyhole or other small aperture into a suitable receptacle. The internal pressure in the siphon is sufficient for this purpose. In order to obtain the maximum disinfecting power from the sulphur dioxid it is necessary to introduce moisture. This may be done by placing open pans of boiling water in the room, or by injecting steam or a fine spray.

THE SULPHUR FURNACE.

The sulphur may be burned in an apparatus of special construction, known as a sulphur furnace, from which the resulting fumes are blown through a system of pipes into the room or hold of a vessel to be disinfected. This method requires expensive and cumbersome machinery and has little to recommend itself over the simpler pot method than that a larger percentage of the gas may be obtained in a given space. The pot method, at best, cannot produce an atmosphere containing more than 4 per cent. of sulphur dioxid, whereas it is theoretically possible to charge a confined space with a high percentage of the gas by means of the furnace. In practice this is not possible without burning a great excess of sulphur and by expending a very long time to accomplish the end. The fumes first entering diffuse with the air, and as the gas continues to flow into the space, it displaces about an equal quantity of this mixture of sulphur dioxid and air, so that, as a matter of fact, in actual practice only about 2.5 to 6 per cent. of the gas is obtained in the holds of vessels by the sulphur furnace.

It is therefore considered advisable, in using the sulphur furnace, to arrange the opening of the pipe admitting the gas into the room as near the floor as possible. In disinfecting the holds of vessels the pipe is usually let down the hatchway until it is near the bilge. The heavy gas collects at the bottom and gradually ascends, displacing the air, so that it is important to allow an opening of some sort for the exit of the air near the top of the compartment being disinfected. This opening should not be closed until the gas escapes freely, when all is to be made tight, excepting the hose conducting the sulphur dioxid.

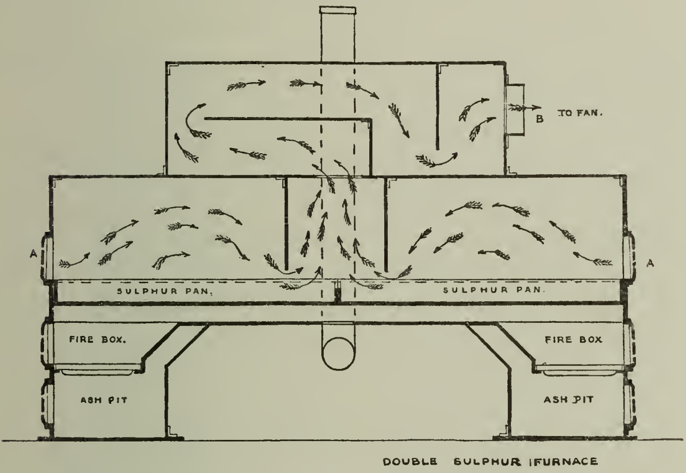
Fig. 44.



End View—Sulphur Furnace.

The sulphur furnace consists of an iron sulphur pan in which the element is burned. Under this pan is a fire-box, with ash-pit and necessary draft. The fire-box is designed to hold a light fire of wood or shavings, and is intended to heat the sulphur pan sufficiently to ignite the sulphur when thrown upon it at the beginning of the operation. This part of the apparatus is entirely unnecessary, for the sulphur may be ignited more simply by means of some alcohol, a few live coals, or by a red-hot spike. When once lighted, there is no trouble in keeping the sulphur burning.

FIG. 45.



LONGITUDINAL SECTION THROUGH SULPHUR FURNACE.

The air enters at A (Fig. 45) through a valve arranged to regulate the amount of flow. It then passes over the burning sulphur in the direction shown by the course of the arrows to the fan. The fumes are compelled to take a devious course around the baffle-plates and angle irons, as shown in the drawing, in order to insure the complete combustion of the oxygen of the air. The angle irons also act as spark-arresters. From B the fumes are sucked to the fan, which is actuated by a steam-engine or electric motor, and which forces the gas through the pipes to the space to be disinfected.

In using the furnace, care must be taken not to run the fan at too high a speed, in which case the oxygen of the air will not all be converted into sulphur dioxid, and furthermore the strong current will carry over a quantity of unconsumed sulphur in a state of fine division. Running the fan at too high a speed also causes overheating of the pipes, or the carrying over of sparks of burning sulphur, thereby rendering possible accidents from fire.

The pipe conducting the fumes from the sulphur furnace to the compartment to be disinfected gives a great deal of trouble. It is apt to become clogged with the sulphur which sublimes in the cooler portions, and unless special care is taken the heat generated is sufficient to burn out and destroy the materials of which the pipe is constructed. Ordinarily this pipe must be 6 to 8 inches in diameter. Rubber hose of this size is not only very costly and heavy, but the sulphur soon vulcanizes the rubber, rendering it brittle and useless. A good pipe for this purpose may be made of light galvanized iron sections 2 or 3 feet long, joined with copper wire to take the strain, and the joint made tight with several layers of canvas, saturated and coated with some fire-proof paint.*

No arrangement is made in this form of apparatus for adding watery vapor to the sulphur fumes, which is necessary to obtain the maximum disinfecting power of the gas.

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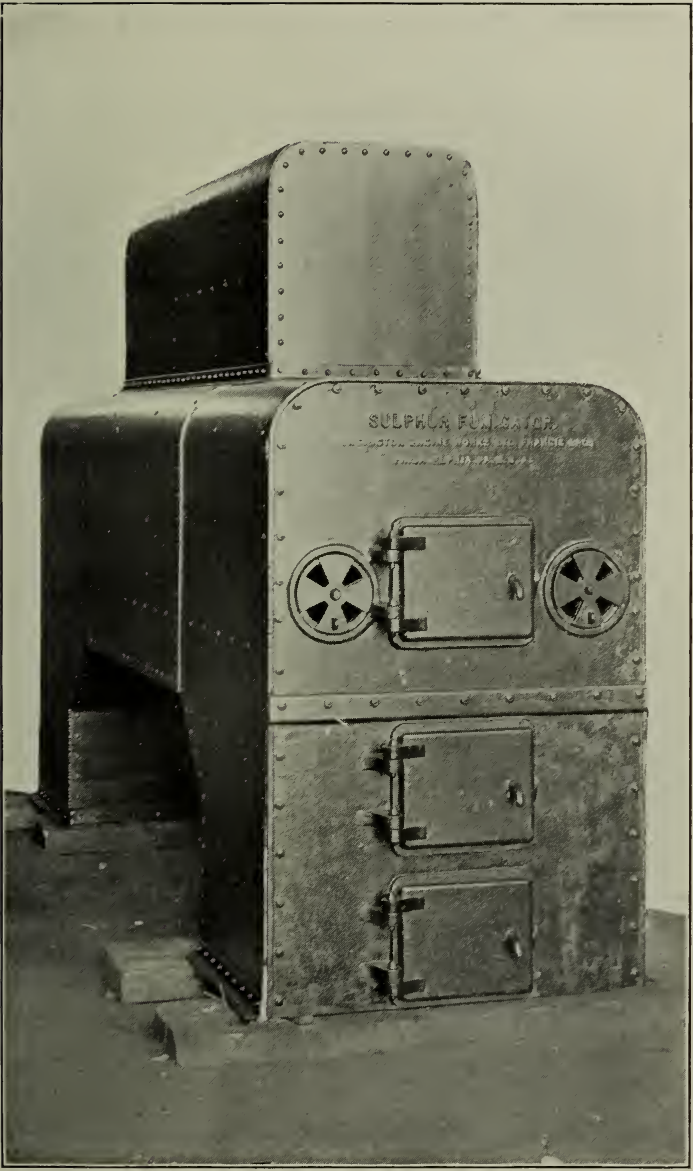
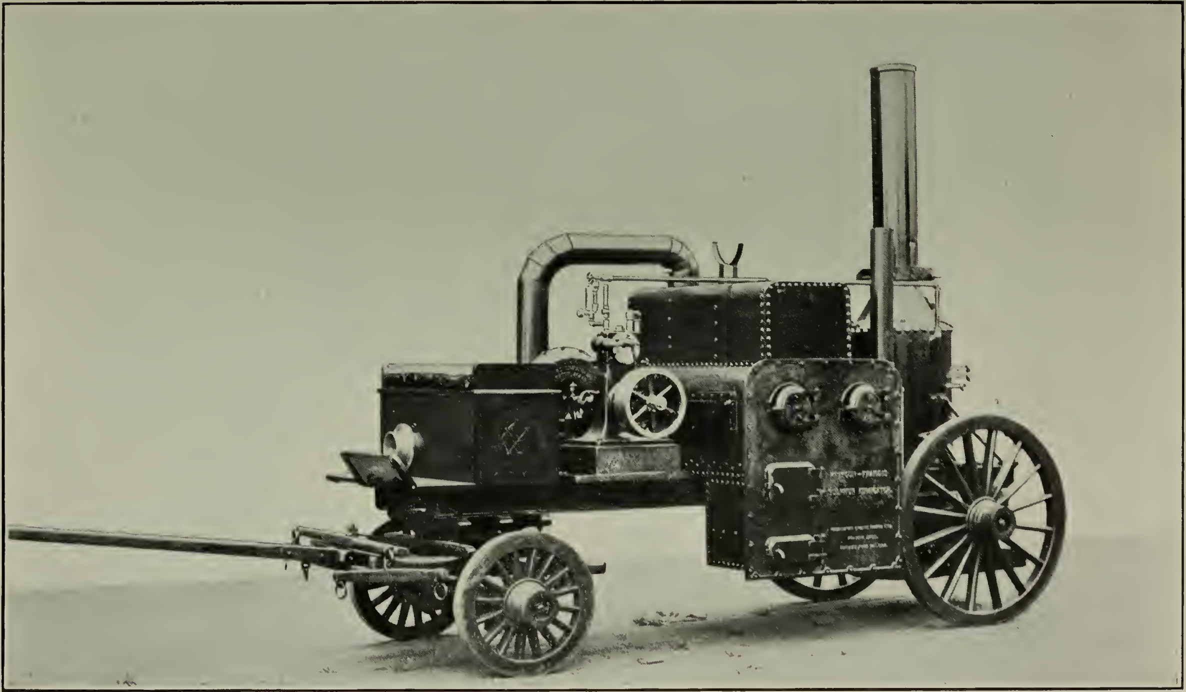
* See the article on this subject in the Annual Report of the Marine Hospital Service for 1897, page 269, by the author.

Fig. 46.



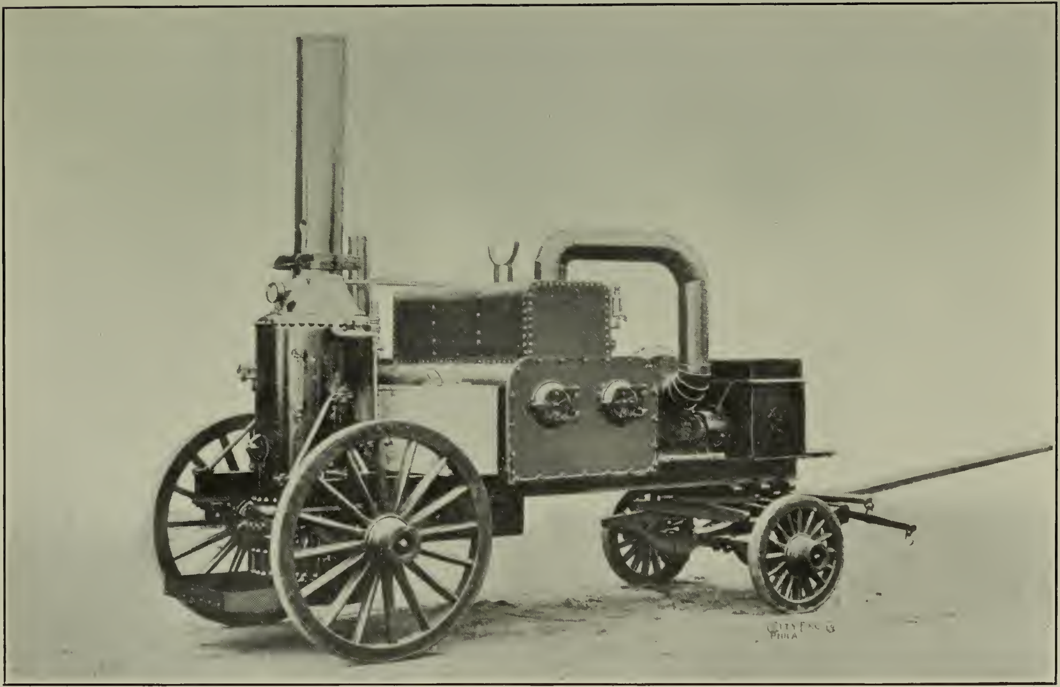
Double Sulphur Furnace.

Fig. 47.



Portable Sulphur Fumigator, Working Side.

Fig. 48.



Portable Sulphur Fumigator, Rear Side.

It is therefore necessary, in dry weather, to add a sufficient quantity of vapor, preferably by means of a steam jet. The air should be saturated. The holds of wooden vessels, in which sulphur fumigation is such a useful disinfecting process, are usually so damp that the addition of more moisture is not necessary.

The *portable sulphur furnace* depicted in the accompanying illustration is a very useful apparatus in municipal work, particularly for the treatment of sewers, warehouses, stables, barns, grain elevators, and similar large rough structures which are infested with vermin. This form of furnace was used with success in the fight against the rats in the sewers of San Francisco, on account of the plague. It simply consists of the sulphur furnace described above, placed upon a truck, so that it can readily be hauled from place to place. With this apparatus the sulphur dioxid can be forced into out-of-the-way places inaccessible to the pot method. The truck is supplied with a small vertical boiler and steam-engine to actuate the fan.

HYDROCYANIC ACID.

Hydrocyanic acid (HCN) is used extensively in the disinfection of nursery, stock and greenhouses, as well as in flouring-mills against weevils, in railroad cars against bedbugs, and in tobacco warehouses against insects in general. This gas is a fatal poison for all the forms of animal life. It is much less destructive to vegetable life. In other words, it is a very powerful insecticide, but a weak germicide. Against organisms no hardier than those of diphtheria and typhoid, it appears, according to Fulton,* to be effective.

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*J. S. Fulton, "American Medicine," May 11, 1901, p. 256.

Like the other gaseous disinfectants, this substance possesses no marked power of penetration.

The extremely poisonous nature of hydrocyanic acid gas makes it necessary to exercise very great care in its employment. In fact, the great danger attending its use forbids its employment about the household. In practical disinfection it may occasionally find a place in the treatment of stables, granaries, outhouses, the holds of ships, and similar uninhabited places, particularly if infested with vermin.

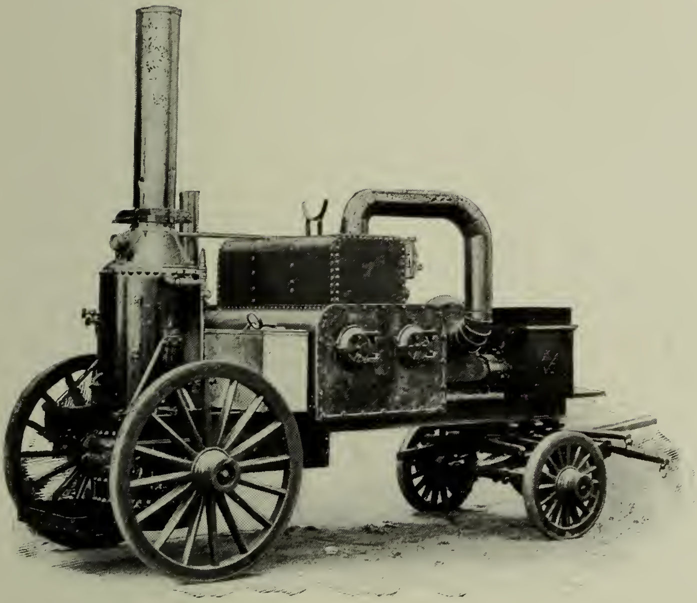
Hydrocyanic gas is lighter than air and has an agreeable, aromatic odor, quite familiar in the flavoring essence of bitter almonds. It is best generated by the action of dilute sulphuric acid upon potassium cyanid, in the following proportions:

Potassium cyanid,	1.0
Sulphuric acid,	1.5
Water,	2.25

The first step is to dilute the acid, which is best done by adding the acid to the water, in a vitrified clay jar or receptacle capable of withstanding the heat. The whole amount of the cyanid must be put into the acid at once, and as the evolution of the gas is very rapid, the operator must be ready to leave the spot immediately. As pointed out by Fulton, it is convenient to tie the cyanid up in a bag, which is lowered into the acid by a cord passing outside of the room. The amount of gas used for plant fumigation, expressed in terms of cyanid, is about 1 ounce, or 25 grams per 100 cubic feet. For room disinfection a greater amount is necessary.

This gas has few advantages over sulphur dioxid in ridding a place of vermin, and its germicidal value is inferior to formaldehyd; and as its poisonous nature is such a serious drawback, it has a very limited place in practical disinfection.

FIG. 49.



PORTABLE SULPHUR FURNACE.

CHLORIN. Chlorin is a germicide of considerable, but uncertain, power. It has little practical usefulness owing to its poisonous and destructive action. Both in its free gaseous state and in its watery solution it has very powerful deodorizing properties. In the free state moisture is necessary for its action. At best this gas is but a surface disinfectant.

Chlorin (Cl) is an extremely irritating gas, and great care must be observed in its employment, for the inhalation of very weak proportions of the gas produces serious irritation, resulting in spasm of the larynx, bronchitis, and even in death. Chlorin (sp. gr. 2.47) is heavier than air, and tends to fall; therefore the vessel generating the gas should be placed in an elevated position, in order to obtain anything like effective diffusion. Carpets, curtains, and fabrics generally are injured by its action, and the element is a very active bleaching agent for all the organic pigments.

The germicidal action of chlorin depends upon its great affinity for hydrogen. So strong is this affinity that it combines with the hydrogen of water in the presence of light, liberating the oxygen in its nascent state, thereby enabling it to exert its power against organic matter. Its value as a deodorant depends upon its power of decomposing the offensive gases of decomposition, such as sulphureted hydrogen and the volatile ammoniacal compounds.

In practice the most convenient method of generating the gas is by decomposing 1½ pounds of chlorid of lime with 6 ounces of strong sulphuric acid. This produces sufficient gas for the disinfection of 1000 cubic feet of air space. Or, the gas may be generated from—

Common salt,	8	ounces.
Magnesium dioxid,	2	"
Sulphuric acid,	2	"
Water,	2	"

Mix the water and the acid together and then pour the mixture over the salt and magnesium dioxid, in a glazed earthenware basin. The basin should rest on sand.

Another method of generating chlorin gas is by adding 4 parts of strong hydrochloric acid to 1 part of magnesium dioxid.

According to Fisher and Proskauer,* in ordinary dry air 5.38 parts of free chlorin per 1000 cubic feet of air space appears to be necessary to kill micro-organisms. If the air be moistened, which may be done by wetting the walls, floors, etc., or by diffusing steam, only 0.3 per cent. by volume in each 1000 cubic feet of air is sufficient, disinfection being completed in five to eight hours. According to these same authors, chlorin gas is a highly unsatisfactory disinfecting agent from a practical standpoint, on account of the impossibility of regulating all the necessary conditions, and the uncertainty of achieving the object to be attained. Sternberg† found that an exposure of six hours to a constant strength of one-half of one per cent. of chlorin was necessary to destroy the potency of vaccine virus.

For the purposes of practical disinfection, Munson very properly states that free chlorin is much inferior to sulphur dioxid, since it is more difficult to control, more dangerous to manipulate, and more destructive in its effects.

OXYGEN.

The disinfecting power of oxygen depends largely upon the physical state in which it exists. For instance, the oxygen in the air has feeble, if any, germicidal properties, while nascent oxygen and ozone are powerful germicides.

The germicidal action of oxygen depends upon its very active property of combining chemically with the albuminous matter of the cell protoplasm. The oxidizing properties of this element, acting upon organic matter, and converting a great part of it into carbon dioxid and water, explains the purifying power of fresh air.

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* "Mittheilung aus dem kaiserl. Gesundheitsamt," II, p. 228.

† "Military Hygiene," Munson, p. 786.

Most bacteria, to grow and multiply, require the presence of oxygen. They are called aerobic. There is a large class of organisms that will not develop in the presence of minute traces of free oxygen. These are called anaerobic. In fact, the oxygen of the air acts like a poison or strong antiseptic for this class of vegetable life, among which are tetanus, symptomatic anthrax, malignant edema, etc. On the other hand, oxygen has no appreciable effect upon the spores of these bacteria.

Pasteur* showed that the cocco-bacillus of cholera attenuates in the presence of the air. He proved that it is the oxygen that causes this phenomenon, by preserving the virulence of a culture when hermetically sealed.

According to the researches of P. Bert and Reynard,† oxygenated water has the power of arresting fermentation and putrefaction. Solutions containing 10 or 12 volumes of oxygen have, according to Lucas-Championnière,‡ a very notable antiseptic power.

OZONE.

Ozone is the allotropic form of oxygen, containing three atoms of that element to the molecule instead of two. In sufficient concentration it is a powerful germicide, and has lately found practical use in the sterilization of water on a large scale, for the use of cities and towns. There is not sufficient ozone in the air normally to exert any appreciable oxidizing or disinfecting properties.

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* "Du l'attenuation du virus du charbon des poules," Pasteur.

† "Infiuence de l'eau oxygenée sur la fermentation," "C. R. de l'Acad. des Sci.," May 22, 1882, and "Gaz. Med.," 1880.

‡ "Sur la valeur antiseptique de l'eau oxygenée," "Acad. de Med.," Dec. 6, 1898.

Ozone is formed by a number of chemical reactions, but in actual practice it is produced by the discharge of electricity in the oxygen of the air. It is a gas with more powerful oxidizing properties than free oxygen. It bleaches indigo and liberates iodin from potassium iodid, which is one of the tests for its presence. Ozone has a peculiar odor familiar about electric dynamos. It has never been obtained free from oxygen, and is regarded simply as a modification of that element, the formula being expressed as O_2O, indicating that three volumes of the gas have been condensed into two.

Ozone is nearly insoluble in water. It is owing to this property that special apparatus is necessary in order to use it for the disinfection of water. In the patented processes the ozone is generated by electric discharges in special apparatus called ozonizers, which produce this substance in proper concentration. The gas is then brought in contact with the water in large columns containing a porous stone. The water trickles down through the porous substance while the ozone enters the column from below, so that there is intimate contact between the water and the gas. The water is sterilized almost instantly, and as the ozone also oxidizes the organic matter and leaves no undesirable chemical residue, the method has very much to recommend it for the central purification of the water-supply of large cities. The method is much too expensive and cumbersome for the disinfection of water on a small scale.

CHAPTER III.

CHEMICAL SOLUTIONS.

General Considerations—Bichlorid of Mercury—Carbolic Acid—The Cresols—Formalin—Potassium Permanganate—Lime—Chlorinated Lime—The Hypochlorites—Ferrous Sulphate—Zinc Chlorid—Soaps.

GENERAL CONSIDERATIONS.

A chemical solution, to be of practical value, must not only be strongly germicidal as shown by laboratory experiments, but must also meet the many exacting requirements of general practice. Such substances are few in number.

Almost any chemical substance, under one condition or another, has the power to retard the development or destroy the activity of microbial life. We need only mention the well-known power of common salt or of sugar, which in sufficient concentration prevents the processes of fermentation and decomposition. In weaker dilutions these same substances, on the contrary, favor the growth and multiplication of almost all the known bacteria.

The undeserved reputation of many so-called chemical disinfectants depends more upon their vile odor or judicious advertising than upon actual efficiency. Only such substances will be enumerated below as by scientific tests and actual experience have proved to be trustworthy.

There is a great difference between the strength of solutions required to prevent fermentation and putrefaction, and the strength required to destroy the causes of these processes. The first are antiseptics, the second are disinfectants, or germicides. For instance, corrosive sublimate solution of the strength of 1 : 15,000 will prevent the growth and development of all bacteria. Even as weak a solution as 1 : 300,000 will prevent the growth and development of some bacteria; whereas it takes a solution of 1 : 1000 to destroy them in a short time. Formalin (40 per cent. formaldehyd) will prevent the development of many bacteria in a solution of 1 : 50,000, while it requires a 1 per cent. solution to kill the germs and their spores.

It is not enough, in applying any agent whose best working strength is known, to use a small volume of the solution of that particular strength. The substance itself must be used in such an amount that it shall be present throughout the whole mass in the proportion required. Thus, an agent that is effective in a 2 per cent. solution cannot be used in that strength to disinfect an equal volume of infected material, since the mixture would then contain but 1 per cent.

Time is an essential factor too frequently disregarded in disinfecting with chemical solutions. Very few chemical disinfectants act instantly, even in strong solutions and under favorable circumstances. The micro-organisms are so often in clusters, or are surrounded by mucoid films, or embedded in nitrogenous materials, that no inconsiderable time is required for the disinfecting solution to penetrate to the germ. If the microbes are dry, it takes a certain time to wet them before the chemical in solution can act. All these and other factors must be added to the time actually necessary for the chemical in solution to destroy the life of the germ after it comes in direct contact with the protoplasm of the cell.

It therefore will not suffice to dip objects to be disinfected into cold solution, momentarily, as is so often done. If the objects are mechanically clean they may be immersed until thoroughly wetted by the solution, and then hung up so that the disinfecting solution may dry, preferably in the sun. Otherwise they should be kept completely immersed a sufficient length of time, depending on the strength of solution, as stated under each chemical. Weak solutions, of course, take a longer time to act than strong solutions.

The temperature so greatly influences their disinfecting power that it is strongly recommended always to use warm solutions in actual practice. Even slight changes of temperature make a great difference. Feeble antiseptic solutions become strong germicides when heated. A good instance of the effect of temperature is given by Heiden,* who found that anthrax spores which survived the effects of a 5 per cent. carbolic acid solution for thirty-six days at room temperature were destroyed in half an hour in the same solution at 55° C. At 75° C. it took only three minutes to kill them; a 3 per cent. carbolic acid solution killed the same spores at this temperature in fifteen minutes, and a 1 per cent. solution in from two to two and a half hours.

The medium in which the germs exist also makes a great difference so far as the power of a germicidal solution is concerned. Behring found, for example, that anthrax bacilli in water are killed in a few minutes with a sublimate solution of the strength of 1 : 500,000. In bouillon it required a strength of 1 : 40,000; while in blood-serum, if the disinfection is to be accomplished in a few minutes, a strength of 1 : 2000 is not always sufficient. Therefore, in the presence of organic matter or filth, stronger solutions and longer exposures are required.

The choice of the chemical selected depends somewhat upon the nature of the substance to be disinfected. For example, bichlorid of mercury is totally inapplicable to the disinfection of albuminous matter. Certain chemicals, too, have a particular power to destroy certain organisms, while they are relatively inert toward others. Taken altogether, therefore, the choice of the chemical, its strength and time of application, the temperature of the solution and its method of employment, are all problems which must be solved for each particular case.

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* "Centralbl. für Bakt.," Bd. IX, 1891, p. 221; and "Archiv für Hygiene," Bd. XV, 1892.

Chemical substances act in a great variety of ways to bring about the destruction of bacteria. It is impossible, as Munson states, to explain in many cases the manner in which disinfection is accomplished by chemical agents, any more than to say that the microbes are poisoned by the disinfectant. In particular instances this is accomplished by a union between the disinfectant and the protoplasm of the bacteria, as appears to be the case with corrosive sublimate or formalin. In some instances the mycoprotein of the cell is coagulated, as in the case of carbolic acid and homologous substances.

According to the newer chemical theories, there are found in watery solutions certain substances in the condition of electric dissociation. These substances are divided into electro-positive (+) and electro-negative (—) components —that is, "ions." The higher the grade of this dissociation, the greater is the disinfecting power of the solution. In the case of the soluble metallic salts, and especially mercury, it depends upon whether in the electrolytic dissociation the metal exists as an independent ion, or whether it exists as a complex ion. In the first case the solution has strong disinfecting properties, in the second these properties are much weaker. In other liquids, as for example alcohol, ether, etc., the metallic salts have very slight dissociation, which according to Krönig and Paul explains the weaker disinfecting power of these solutions. The disinfecting power of metallic salts depends, furthermore, not only upon the specific influence of the metal ion, but also upon the other ions, and upon the unassociated parts of the metallic salts.

The reaction of the solution and of the medium to be disinfected varies with the substance employed. Thus, lime is an alkali, and if used to disinfect an acid substance, enough must first be added to neutralize the medium, and then an additional amount of the lime must be added necessary to accomplish the disinfection. In the same way, if mercuric chlorid is added to solutions containing sulphids, caustic alkalies, or certain metallic salts, sufficient must be added in order to first precipitate these substances and then enough more added to exert its disinfecting action. Likewise, the greater the number of germs to be destroyed, the greater the amount of disinfectant required to accomplish the purpose.

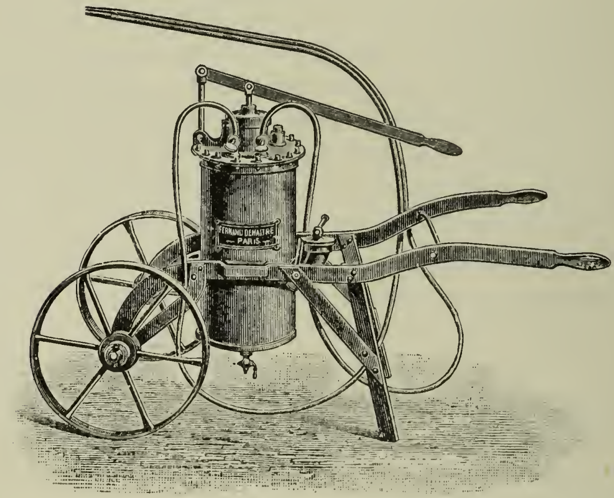
METHODS OF USING CHEMICAL SOLUTIONS.

There are various ways of applying chemical solutions for disinfecting purposes. No method is trustworthy that does not thoroughly wet the object with the solution so that there may be direct contact between the substance in solution and the contagious principle against which the process is directed.

As a rule this may best be accomplished by immersing the infected object in the solution. When this is not practicable, the solution must be applied to the object. A favorite way of applying disinfecting solutions to surfaces, such as walls, ceilings, the holds of ships, and other rough structures, is by means of a hose. The pressure is supplied either by elevating the tank containing the solution or by means of a pressure pump. As bichlorid of mercury is practically the only disinfectant used in this way, the pump should be made of iron and have no copper, brass, or steel parts exposed to the corroding action of the solution.

In applying the disinfecting solution to the surfaces of a room or the hold of a ship the operator should begin at one corner of the ceiling, wetting that first, and then go over every portion of the walls systematically, from above downward. The floor comes last.

Fig. 50.



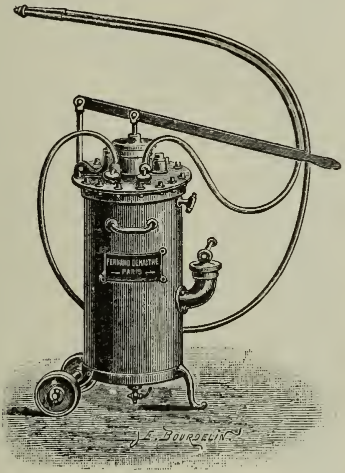
Apparatus for Spraying Disinfecting Solutions in a Nebulous Spray.

Solutions thus applied remain but a short time in contact with the surfaces to be disinfected. It is therefore an advantage to have the solution hot and strong, and to have sufficient pressure in order to obtain the mechanical effect produced by a vigorous stream.

A good way of applying disinfecting solutions to surfaces is by means of mops, brooms, and the like, for we add the mechanical action to the power of the germicide.

The pulverizer is very popular in France for the disinfection of walls and other surfaces with solutions of bichlorid of mercury. The apparatus for this purpose consists of a metal cylinder fitted with a simple force pump which compresses the air in the reservoir. The solution does not come in contact with the pump. The current of air driven through the one tube sucks the solution through the other, and sprays it from the nozle in a nebulous cloud, similar in principle to the well-known hand atomizers.

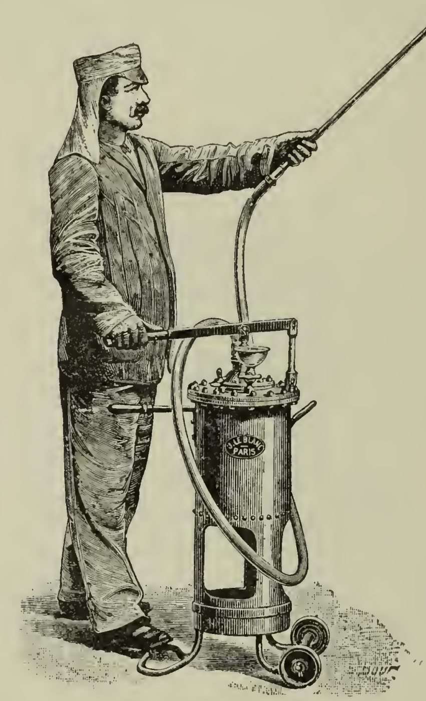
FIG. 51.



It is easy to demonstrate, by using a colored solution upon a white wall or sheet, that a liquid sprayed in this way does not wet the entire surface. The method is therefore an unscientific and unreliable one when used with a non-volatile chemical.

The pulverizer, as used by the disinfecting corps in Paris for the treatment of walls and other surfaces with a fine spray of bichlorid of mercury solution, is shown in the accompanying illustrations.

FIG. 52.



The suits of the operator are made of canvas and are taken off in the room at the completion of the process, and placed in the bag with the other articles for steam disinfection.

BICHLORID OF MERCURY.

Bichlorid of mercury or mercuric chlorid, commonly called corrosive sublimate, is one of our most valuable and potent germicides. It destroys all forms of microbial life in relatively weak solutions. It kills both the germs and their spores, and therefore can be used as a disinfectant against all the known forms of infection. It is not a deodorant.

The disadvantages of bichlorid of mercury are that it corrodes metals, forms insoluble and inert compounds with albuminous matter, and is very poisonous. These disadvantages place distinct limitations upon its use.

Mercuric chlorid ($HgCl_2$) is a white, crystalline mass, of heavy specific gravity—5.43. It volatilizes somewhat more readily than mercurous chlorid (calomel) even at room temperature. On account of this property caution must be observed in using bichlorid solutions about living rooms, some instances of poisoning having been traced to this use. It is therefore well to follow the bichlorid with clear water, and a mechanical cleansing is always in order.

Bichlorid of mercury will dissolve in 16 parts of cold water and 3 parts of boiling water. As it is soluble with much difficulty in water, it is convenient to keep a saturated alcoholic solution on hand, and use this to make the watery solutions. A 25 per cent. solution may readily be made in alcohol, and by the addition of hydrochloric acid or ammonium chlorid will keep indefinitely. This would be rather expensive for making up the large quantities required in flushing the holds of ships or other extensive surfaces.

The solution may be facilitated by a little device pointed out by Geddings. The correct quantity of the bichlorid is weighed out and placed in a canvas bag which is hung over the faucet so that the water will run through it into the tank or receptacle holding the solution. If this method is not convenient, the bichlorid must be pounded to a powder and care must be exercised that it is all dissolved before using. The solution of bichlorid is facilitated by the presence of hydrochloric acid, or a chlorid, such as ammonium chlorid or common salt. Twice the quantity of these substances to the quantity of bichlorid used is added. If the solution is to be pumped or otherwise come in contact with metals, it is better to use the chlorids than the acid, because the acid solution of bichlorid is very destructive to the metal parts of the pump, and to the couplings and nozle of the hose, particularly if made of copper or brass.

Sea-water contains about 4 per cent. of salt, and is well suited for making bichlorid solutions. It is extensively used at the seaport quarantine stations for this purpose.

La Place first pointed out that the addition of a small amount of an acid to the solution of bichlorid of mercury greatly increases its efficiency, and by lessening the formation of insoluble albuminates also increases its power of penetration. This has latterly been denied by Krönig and Paul,* who assert that the addition of sodium chlorid to watery solutions of bichlorid diminishes its power. They found that potassium chlorid or hydrochloric acid has the same effect.

The germicidal action of bichlorid solutions seems to depend upon the reaction that takes place between the bichlorid in solution and the mycoprotein of the germ. This reaction is a chemical one, and of course requires direct contact between the albuminous matter of the germ and the bichlorid of mercury in solution, as well as a certain time and concentration to effectually destroy the life and virulence of the cell. Geppert † has shown that in the reaction that takes place between bichlorid of mercury and the spores of anthrax, the vitality of the latter may seem to be lost, but that the bichlorid may be precipitated from its combination by the action of ammonium sulphid, which restores the vitality of the spore.

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* "Zeitschr. f. physik. Chem.," Bd. XXI, 1896, p. 449; and "Zeitschr. f. Hygiene," Bd. XXV, 1897, p. 65.

† "Berl. klin. Wochenschr.," 1889, No. 36; and "Deutsch. med. Wochenschr.," 1891, No. 37.

Like a great number of chemical reactions, the combination of the bichlorid solution with the germ protoplasm is very much hastened by the aid of heat. The action of the moist heat itself plus the effect of the bichlorid makes hot solutions of this chemical a very powerful germicidal agent.

Bichlorid of mercury is decomposed by lead, tin, copper, and other metals. It therefore should not be made or kept in metal receptacles. Lead pipes are rendered brittle and worthless by passing this solution through them. Care must therefore be exercised in using this substance about water-closets and plumbing.

On account of the property that this substance has of uniting with albuminous matter to form insoluble and inert compounds, it cannot be used for the disinfection of media containing much organic matter. It is totally inapplicable to the disinfection of sputum, excreta, and the like, for it forms a coagulum which prevents the further penetration of the bichlorid. It also unites chemically with the sulphids and the caustic alkalies, so that it should not be employed as a disinfectant when these substances are present in any considerable amount. If it is used, enough of the bichlorid must first be added to precipitate these chemical substances and then a sufficient additional quantity so that the bichlorid of mercury will be present in the desired proportion.

To diminish the danger from accidents bichlorid solutions in households and hospitals should be colored with permanganate of potash, or indigo, or one of the anilin dyes.

The germicidal power of bichlorid of mercury has been very carefully studied in many laboratories, so that we are in possession of definite knowledge as to the exact strength and time necessary to accomplish disinfection.

A solution of 1 : 1000 is ample for the destruction of all the non-spore-bearing bacteria at the ordinary temperatures, provided the exposure is continued not less than half an hour. Many bacterial cells are killed at once when brought in direct contact with a solution of this strength, and the great majority are destroyed within fifteen minutes; but the extra time as given allows for penetration, which is usually required in actual practice.

Solutions of bichlorid of mercury of the strengths of 1 : 800 and 1 : 500 are very strong germicides and will kill non-spore-bearing infections in a short time.

For spores a solution of 1 : 500 is necessary and an exposure of one hour.

Articles may be disinfected by immersing them in a solution of 1 : 2000, provided that the exposure is not less than two hours.

A strength of 1 : 15,000 is sufficient to prevent putrefaction and fermentation.

CARBOLIC ACID.

Carbolic acid makes a very useful disinfecting solution with a wide range of application. It should not be depended upon to kill spores. As it does not coagulate albuminous matter as actively as corrosive sublimate, it may be used for the disinfection of soiled clothing and bedding, as well as for excreta and the like. However, it is not so trustworthy for these purposes as some of its homologues, such as tricresol or lysol.

Carbolic acid is also known as phenic acid, phenol, phenyl alcohol, and coal-tar creasote, and is represented by the chemical formula $C_6H_6O = C_6H_5OH$. It is produced in the dry distillation of coal and is the chief constituent of the acid portion of coal-tar oil. Pure phenol crystallizes in long, colorless needles. The commercial product forms a crystalline mass, which is apt to turn reddish in time, and in contact with moist air deliquesces to a brown liquid. Carbolic acid has a penetrating odor, a strong burning taste, and is a corrosive poison.

The carbolic acid of commerce contains impurities, such as the cresols and higher homologues, some of which have a higher germicidal value than pure carbolic acid itself. The commercial product also contains tar oils which are totally lacking in bactericidal properties. The cruder chemical containing these impurities has been shown to be superior to the highest grades of the refined acid, which is practically pure phenol.

At ordinary temperatures carbolic acid is soluble in about 15 parts of cold water—that is, a saturated solution contains between 6 and 7 per cent. It is commonly used in solutions of 3 to 5 per cent., which are entirely trustworthy for the destruction of all infectious processes due to non-spore-bearing organisms.

The acid dissolves in water with some difficulty; care should therefore be exercised to mix it thoroughly by agitation, preferably in warm water.

It is not destructive to fabrics, colors, metals, or wood, in the strengths used, and therefore may be employed for the disinfection of a great variety of objects. The fact already mentioned that it does not actively coagulate albuminous matters renders it suitable to the disinfection of urine, excreta, soiled linen, and the like.

There has been much disparagement of carbolic acid lately because laboratory tests have clearly demonstrated that it cannot be depended upon to kill spores. This limits, but does not destroy its usefulness, for fortunately the great majority of the epidemic diseases of man are due to non-spore-bearing bacteria. Carbolic acid should not be used to destroy the infection of tetanus, anthrax, malignant edema, and other diseases due to spore-bearing bacteria.

A 1 per cent. carbolic acid solution or even a 2 per cent. solution has no certain effect upon anthrax spores. A 3 per cent. solution requires seven days, a 4 per cent. solution three days, and a 5 per cent. solution two days to kill anthrax spores. These figures do not apply to all varieties of anthrax spores, for there are some, as v. Esmarch* found, that can withstand forty days' immersion in a 5 per cent. watery solution of the acid. Teuscher † reports a resisting variety of anthrax spore that was not killed after four and a half days' immersion in pure crystallized phenol, kept liquid in the incubator.

Very much weaker solutions are effective for non-spore-bearing bacteria. For instance, the germs of cholera, plague, typhoid, diphtheria and erysipelas are killed, according to Behring, by one hour's immersion in a ½ per cent. solution, while a solution of 1 to 1½ per cent. will destroy these non-spore-bearing micro-organisms in one minute.

In general practice carbolic acid is used in from 3 to 5 per cent. solutions, and an exposure of no less than half an hour. Clothing and fabrics require deep penetration, and are usually left in the solution one hour.

THE CRESOLS.

Tricresol is about three times as powerful a disinfectant, bulk for bulk, as carbolic acid. A 1 per cent. solution is effective for all ordinary purposes. The presence of albuminous matter in fluids to be disinfected does not interfere to any serious extent with its prompt and certain germicidal action. Tricresol has another advantage over carbolic acid in that it may be depended upon to kill spores.

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* "Zeitschr. f. Hygiene," Bd. v, 1888.

† "Zeitschr. f. Hygiene," Bd. IX, 1890, p. 510.

Tricresol consists of a mixture of ortho-, meta-, and paracresol. Metacresol is a liquid, the other two are solid crystalline bodies, having a low melting-point. These cresols are some of the impurities found in commercial carbolic acid. The cresol group forms the next higher homologue to phenol, one atom of hydrogen being replaced in the latter by the methyl radical, CH_3. The cresols are not very soluble in water, but solution may be brought about by the soaps or by cresol salts.

The cresols accompany phenol in coal tar, from which they are obtained. Tricresol is a clear or pinkish-colored syrupy liquid. About a 2½ per cent. solution can be made of it in water. It is somewhat less poisonous than carbolic acid. Its uses are the same. It is commonly employed in a 1 per cent. solution.

There are a number of other well-known preparations of the cresols now extensively used in surgical and hospital practice. The following from Harrington are given as trustworthy disinfectants:

Creolin contains 10 per cent. of cresols and a small amount of phenol held in solution by soap. It is a dark brown, thick, alkaline liquid, and forms a turbid, whitish emulsion with water. It is at least equal, and perhaps superior, to phenol.

Lysol contains about 50 per cent. of cresols, with neutral potash soap. It is a brown, oily liquid and mixes with water in all proportions, forming a soapy, frothy liquid. It is more powerful than phenol and ranks with tricresol as a germicide.

Saprol: This liquid contains 20 per cent. of mineral oil and 80 per cent. of crude carbolic acid. It is lighter than water, and when thrown into it diffuses over the surface in a thin layer, which gradually yields its active ingredients to the strata below, so that in the course of a day the water becomes impregnated to the extent of 0.34 per cent. It is superior as a general disinfectant and deodorant to carbolic acid.

Solveol is a concentrated aqueous solution of the cresols with sodium cresotinate. It contains over 2½ per cent. of cresols. It is unirritating and much less toxic than carbolic acid. As a disinfectant it is the equal, if not the superior, of any of the cresol preparations.

Solutol is a solution of about 60 per cent. of cresols in sodium cresol. Those who have tested this preparation claim for it superior germicidal powers to creolin, lysol, solveol, and phenol.

FORMALIN SOLUTIONS.

Formalin is a very valuable disinfectant, with a wide range of usefulness in general practice. This liquid is superior to bichlorid of mercury for many purposes, especially as its action is not retarded by the presence of albuminous matter. Formalin does not injure most articles, and it is not poisonous. It is a true deodorant.

Formalin, also known as formol and under various other trade names, consists of a 40 per cent. solution of the substance formaldehyd (CHOH) dissolved in water. Formaldehyd is a gas at ordinary temperatures, and it must be condensed in order to obtain it in concentrated solution. Formalin, therefore, consists of a solution of one of the polymeric forms of formaldehyd, especially paraformaldehyd. See page 87.

The liquid is a clear solution, giving off an appreciable odor of formaldehyd gas. It is exceedingly irritating, but not toxic. Formalin solutions are rather unstable. There is a constant loss by evaporation if the liquid is not kept well corked, and especially in cold weather the formaldehyd precipitates as a white substance, which consists of one of the polymeric forms of formaldehyd known as trioxymethylene. Formalin usually contains 10 per cent. of wood alcohol, which increases the solubility and stability of the formaldehyd.

Hot formalin attacks iron and steel, and therefore cannot be used for the disinfection of such objects. It does not attack copper, brass, nickel, zinc, and other metallic substances.

In causes no diminution in the strength of textile fabrics, and has no bleaching or other deleterious effects upon colors. Formalin solution renders leather, furs and skins brittle as a result of the union that takes place between the formaldehyd and the organic matter of these articles, and they should therefore be disinfected by another process.

The formalin as found upon the market is acid as a rule, due probably to formic acid. For this reason the solution is apt to spot the delicate colors of silks and fine stuffs. Even water will do this. Such articles should be disinfected with formaldehyd gas.

A 4 per cent. solution of formalin (containing 40 per cent. formaldehyd) in water is about the equivalent of a 1 : 1000 solution of bichlorid of mercury, or superior to a 5 per cent. solution of carbolic acid.

It must be borne in mind that in speaking of a solution of formalin, a solution is meant of the liquid containing 40 per cent. formaldehyd. That is to say, a 1 per cent. solution of formalin would contain that liquid in the proportion of 1 to 100, but would contain the substance formaldehyd in the proportion of 1 to 250.

Feces are deodorized instantly by a 4 per cent. solution of formalin, and are rendered sterile at the end of ten minutes when mixed with an equal volume of a solution of this strength.

According to Park and Guerard, a 3 per cent. solution will kill anthrax spores in fifteen minutes; a 1 per cent. solution will kill all other germs in one hour, and most germs in thirty minutes.

There is some discrepancy as to the percentage of formalin solution necessary to accomplish trustworthy disinfection in general practice. Taking into account the deterioration of the solution with age, and allowing an excess as an element of safety, it is recommended to use a 5 per cent. solution for the purposes of general disinfection.

Formalin is very useful for the disinfection of urine, excreta, sputum, and other albuminous matters. It combines with, but does not coagulate, the albuminous matter, and penetrates deeply.

Formalin is a true deodorant. It does not mask one smell with another, but unites with the albuminous matter to form new compounds that are both odorless and sterile.

On account of the non-toxic properties of formalin it may be used to disinfect certain kinds of food products. At quarantine stations large quantities of bulbs, roots, nuts, fruit, and similar articles coming from plague- or cholera-infected regions are disinfected by immersion in a 5 per cent. solution of formalin. This treatment does not injure their food value. Bulbs, roots, and fruit treated by this method will keep from rotting a much longer time than those not treated.

There is a great difference between the antiseptic and the germicidal value of formalin. That is to say, a very minute amount—1 in 25,000 or 50,000—is sufficient to inhibit the growth and development of bacteria, whereas it requires a 1 to 4 per cent. solution to kill bacteria in a short time. A very minute trace added to milk or wine or other fluids will preserve them a long time from spoiling.

POTASSIUM PERMANGANATE.

Potassium permanganate is a germicide of undoubted power, but of very limited application in general practice, on account of the readiness with which it is reduced and rendered inert by organic matter. Even in weak solutions it destroys micro-organisms of high resistance, and despite its limitations it ranks high on the list of disinfectants for certain definite purposes, more particularly in surgical practice and for the purification of water.

Potassium permanganate ($K_2Mn_2O_8$) is a dark purple, crystalline substance, with a sweet astringent taste. A few crystals impart to a large quantity of water a rich purple tint, which is destroyed by organic matter and deoxidizing agents. It is soluble in 16 parts of cold and 2 parts of boiling water. The stains produced by potassium permanganate may be removed by a solution of oxalic acid, muriatic acid, or simple lemon juice.

Potassium permanganate readily gives up its available oxygen in contact with organic matter or oxidizable mineral substances, and it is the free nascent oxygen that is the true disinfecting agent Unfortunately, as pointed out by Harrington, for its use as a general disinfectant a small amount of organic matter requires a very large amount of the salt for its complete oxidation. Thus, 1 ounce of liquid feces or of urine can reduce such an amount that it is estimated that the sterilization of the total twenty-four hours' excreta of one person would cost five dollars.

Sternberg found a solution of 1 : 833 sufficient to kill pus cocci in two hours. Koch found that a 5 per cent. solution killed spores in one day. Loeffler found the bacillus of glanders destroyed in two minutes by a 1 per cent. solution.

Krönig and Paul * found that a 1 per cent. solution of potassium permanganate, with the addition of 1 per cent. hydrochloric acid, becomes an extraordinarily strong disinfecting solution. Resistant anthrax spores are killed in two minutes. According to these authors this solution is not equaled by a 5 per cent. sublimate solution.

Water contaminated by organic matter may be purified and rendered palatable by adding drop by drop a solution of permanganate until the pink color of the water ceases to be destroyed after the lapse of twenty-four hours. The clear liquid may then be decanted and used.

On shipboard, in wells, and other places where there is a limited amount of water suspected of being infected with cholera, typhoid, or dysentery, enough of the permanganate is sometimes added to give the water a slight tinge of color. This method of purifying the water, which is in rather common use in certain parts of the world, cannot be compared in efficiency with boiling. The strong solution may be used to disinfect the water-tanks and casks themselves.

The toxicology of potassium permanganate is important on account of its use in drinking water. Internally 8 to 10 grains have been taken, without injury, in a very dilute solution. Two grains have produced symptoms of an irritant poison.

LIME.

Lime, or quicklime, is a very caustic substance, useful for the destruction of organic matter as well as germ life. On account of its efficiency and cheapness it is a valuable addition to the list of practical disinfectants.

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* "Zeitschr. f. Hygiene," Bd. xxv, 1897, p. 89.

Lime, or calcium oxid (CaO), also known as quicklime, is one of the alkaline earths. It is not so caustic as the alkalies, having a less affinity for water. It is obtained by calcining native calcium carbonate ($CaCO_3$), such as chalk, limestone, or marble, by which the carbon dioxid is given off and the calcium oxid (lime) remains behind.

Slaked lime, or calcium hydrate ($Ca(OH)_2$), is prepared by adding one pint of water to two pounds of lime. The lime absorbs about half its weight of water. The mass becomes heated and the air escapes from the pores of the lime with a hissing noise. The result is calcium hydrate or slaked lime. Exposed to the air, the slaked lime will absorb still more water and also carbon dioxid, converting it into calcium carbonate, which is inert so far as its disinfecting power is concerned. Freshly slaked lime should therefore always be used.

Whitewash is slaked lime mixed with water. It is commonly used for the disinfection, sweetening, and brightening of the walls of cellars, rooms, barracks, barns, stables, poultry houses, and out-buildings generally. Whitewashing is a satisfactory method of destroying disease germs that may have lodged upon such surfaces.

Milk of lime is slaked lime mixed with about four times its volume of water, to the consistency of a thick cream. It is useful in the disinfection of excreta and privy vaults. Air-slaked lime must not be used in the preparation of whitewash or the milk of lime, freshly slaked lime being necessary to accomplish disinfection. Calcium hydrate is insoluble and settles to the bottom; the milk of lime must therefore be agitated to restore its homogeneous character before it is used. Milk of lime is most powerful when freshly prepared. In contact with the air it changes to the inert carbonate, and should therefore not be used if more than a few days old, unless carefully protected from contact with the air.

The researches of numerous scientists, though differing somewhat in certain unimportant particulars, have confirmed the conclusions of the earlier investigators as to the great practical value of lime as a germicide. Liborius * demonstrated the value of lime in the destruction of the bacteria of typhoid fever and cholera. He found that lime-water containing 0.0074 per cent. destroyed the former in a few hours, and lime-water containing 0.0246 per cent. destroyed the latter in the same time. Cholera bouillon cultures, containing numerous coagula of albumin, such as would be present in cholera discharges, were completely disinfected within the course of a few hours by 0.40 per cent. of pure lime or 2 per cent. of ordinary crude lime. He recommended the employment of the pure dry powder or of milk of lime containing 20 per cent. of crude lime. Similar favorable results have been obtained by many other workers.

Lime is particularly valuable in the disinfection of excreta. The lime in one form or another must be well incorporated with the mass, and enough must always be added in order to make the reaction of the mixture distinctly alkaline. Sternberg recommends the freshly prepared milk of lime containing about 1 part by weight of hydrate of lime to 8 parts of water. This should be used freshly prepared and added in quantity equal in amount to the material to be disinfected. The mixture should be allowed to stand at least two hours before final disposal.

Fortunately, this valuable disinfecting agent is very cheap, so that it can be used with a liberal hand in excess of the amount which scientific tests find necessary.

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* "Zeitschr. f. Hygiene," II, p. 25, quoted by Harrington, p. 504.

Lime has been used in very early times in connection with the disposal of the dead. The method is an admirable one for the burial and disinfection of bodies dead from a contagious or infectious disease. The body should be surrounded, in a tight coffin, with twice its weight of fresh unslaked lime, without the addition of water or moisture in any form.

CHLORINATED LIME—"CHLORIDE OF LIME."

Chlorinated lime was used as a disinfectant and deodorant long before bacteriology was a science. The work of Sternberg ably proved that the confidence placed in this substance from an empiric standpoint is justified by scientific tests. Chlorinated lime ranks about with unslaked lime in power and value as a germicide, and has about the same uses in practical disinfection.

Chlorinated lime, popularly miscalled "chloride of lime," is a soft, white, friable substance, and is known also as bleaching powder. It has a peculiar chemical composition and is somewhat unstable. Owing to its affinity for moisture, which it slowly absorbs from the air, it becomes pasty and loses some of its chlorin. Freshly prepared chlorinated lime should have a very slight odor of free chlorin. A strong odor of this gas indicates that decomposition of the substance is taking place, and the loss of chlorin sensibly diminishes its disinfecting power. It should therefore only be used when freshly prepared, or when kept in air-tight receptacles.

Chlorinated lime is made by passing nascent chlorin gas over moist calcium hydrate (unslaked lime). Concerning its exact chemical composition there is some disagreement. It is represented by the formula $CaOCl_2$, or $ClCaOCl$, or $Ca(ClO)Cl$. According to the United States Pharmacopeia it should contain not less than 35 per cent. of available chlorin. The British standard is 33 per cent., and the German 25 per cent.

It is very insoluble in water; only about a 1 per cent. solution can be made.

The solution has an indefinite composition, but is generally admitted to contain calcium hypochlorite ($CaClCaClO_2$), which is its principal disinfecting constituent; calcium chlorid ($CaCl_2$), which has a great affinity for water, and calcium hydrate, $Ca(OH)_2$, which is largely insoluble. The calcium hypochlorite, upon which the efficiency of the solution largely depends, is readily broken up, even by the carbon dioxid found in the air and water, into hyperchlorous acid, and this acid is so unstable that even in the presence of light it is decomposed into hydrochloric acid and free chlorin, both of which are active germicides. The solution is highly alkaline and has feeble bleaching powers.

Its action as a deodorant depends not only upon its destructive influence upon organic matter and its germicidal properties, but also upon its great affinity for water, thus acting as a desiccant; as well as upon its power of combining with hydrogen sulphid and the volatile ammoniacal compounds of decomposition and decay.

Chlorinated lime not only bleaches, but is destructive to fabrics. If the solution is employed for the disinfection of infected bed linen and washable clothing these articles must, after a not too long immersion, be most thoroughly washed in plenty of fresh water. A solution known as the "American Standard," containing 6 ounces of the powder to the gallon, is largely used for the disinfection of discharges and for the scrubbing of floors and other woodwork.

The chlorinated lime may be used either as a dry powder or in solution. As a dry powder it is very generally used by strewing it in damp corners of cellars, privies, and similar places, where it acts as a deodorant and desiccant. The dry substance may also be used to disinfect excreta. For this purpose enough of the chlorinated lime must be added and well incorporated with the mass to make a 4 per cent. solution.

In the United States Army a 4 per cent. strength of chlorinated lime in solution is officially prescribed for use in the disinfection of the excreta of the sick, it being specially stated that the chlorinated lime so used should be of good quality and not have undergone decomposition.

Chamberland and Fernbach * advise that the solution of chlorinated lime be made by covering one part of the bleaching powder with an equal amount of water. After standing an hour the mixture is filtered and a greenish-yellow liquid obtained. One part of this solution is added to ten times its volume of water, for application to the surfaces to be disinfected. As a result of their investigations it is claimed that for purposes of disinfection this weak solution is fully as efficacious as a stronger one. If possible, the solution should be applied hot, and the room which is being disinfected should also have its temperature elevated.

THE HYPOCHLORITES—LABARRAQUE'S SOLUTION.

Calcium hypochlorite ($CaClO_2$) is one of the disinfecting substances found in the aqueous solution of chlorinated lime, and it has just the same uses as that solution. According to Reed, calcium hypochlorite must have a chlorin strength of 0.25 per cent., otherwise it cannot be relied upon as a disinfectant.

Labarraque's solution is an aqueous solution of several chlorin compounds of sodium, chiefly sodium hypochlorite

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* Munson, "Military Hygiene," p. 780.

(NaClO) and sodium chlorid (NaCl), and should contain at least 2.6 per cent. by weight of available chlorin. The solution is clear and colorless when pure. If prepared with an excess of chlorin it is yellowish in color. It has a feeble odor of chlorin and bleaches indigo, litmus, and vegetable dyes like chlorin gas, but less energetically.

Its germicidal properties depend upon the liberation of the chlorin set free by the decomposition of the sodium hypochlorite.

In practice this solution diluted with water (1 to 4) is mainly used for the disinfection of the person, but as it is more expensive and somewhat less efficient than the solutions of chlorinated lime, it has no advantages over that substance.

FERROUS SULPHATE.

Ferrous sulphate has long been valued as a disinfectant on account of its power as a destroyer of bad odors, and has been extensively used, being a comparatively cheap substance. Its germicidal power has been shown by laboratory tests to be very feeble, even in strong solutions, so that it cannot be depended upon as a trustworthy disinfectant.

Ferrous sulphate, $FeSO_4$, commonly called green vitriol, iron vitriol, or copperas, consists of large bluish-green crystals which slowly effloresce and oxidize in the air. It is soluble in about twice its weight of cold water.

Miquel places its antiseptic power at 1 : 90. Sternberg found that in solutions of 1 : 200 it failed to prevent the development of micrococci, and of putrefactive bacteria in bouillon placed in the incubator over forty-eight hours. Leitz found that a 5 per cent. solution required three days' exposure for the destruction of the typhoid bacillus. Koch found that a 5 per cent. solution failed to destroy anthrax spores in six days.

Ferrous sulphate, therefore, judging from the evidence before us, has no claims to be considered a germicide, and has such feeble disinfecting powers that it cannot be depended upon to destroy the contagium, even of non-spore-bearing infections.

At best, then, ferrous sulphate is limited in use to the destruction of the odors arising from fecal matter, and even for this purpose it is not always successful, for Foote * has shown that it sometimes makes a bad odor worse, through chemical action on organic compounds produced in the process of putrefaction. Munson points out the fact that it does not impair the fertilizing value of matter to which it is applied. In practice he recommends 5 parts of the iron salt for each 100 parts of the total contents of the latrine vault as essential to efficiency. The salt must always be applied in solution, and thoroughly incorporated with the mass. In the French army ferrous sulphate is much used for the disinfection of latrines in a 10 per cent. solution. It is officially laid down that at least 250 c.c. of such a solution should be used per day for each person using the latrine.

ZINC CHLORID.

Zinc chlorid was at one time highly valued as a disinfectant and is still extensively used, despite the fact that it stands rather low in the list of germicidal agents. It has even weaker powers as a disinfectant than ferrous sulphate, and cannot be recommended as trustworthy. It has some value as a deodorant.

Chlorid of zinc, ZnCl, is a white, translucent, friable substance, very soluble in water and very deliquescent. It is a strong dehydrating substance and removes oxygen and hydrogen from organic bodies in the form of water, which partly explains its action as a deodorant, as well as its effect upon germs.

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* "Amer. Jour. of the Med. Sci.," xc, p. 329.

According to Miquel, it is antiseptic—that is, prevents the growth and multiplication of bacteria in the proportion of 1 : 526. Koch found that anthrax spores germinated after being immersed in a 5 per cent. solution for thirty days. Sternberg found that a solution of the strength of 1 : 200 destroyed Micrococci pasteuri in two hours.

SOAPS.

Ordinary soaps have a limited disinfecting power. According to Behring,[*] this depends upon their alkalinity; but Serafini[†] more correctly points out that the free alkali present, even in concentrated soap solutions, is so small in amount that it can exert no disinfecting action whatever, and that neither the alkali nor the fatty acid, but the combination of the two, is the effective agent.

Unfortunately, the disinfecting power of soap solutions is not marked enough to make them trustworthy disinfectants, despite their great value as detergents. The common commercial soaps, especially the colored soaps, are frequently of very poor quality, containing rosin instead of the fatty acids, and are not to be depended upon. The soft soaps should also be avoided on account of the presence of all the impurities of the fat and alkali from which they are made. There are other conditions which render the use of soaps uncertain, the chief of which is the hardness of the water.

The laboratory experiments of numerous investigators have shown that soap solutions have a decided power to destroy some of the less resistant forms of bacteria. It has also been shown that soap, even in strong solution and with prolonged exposure, cannot be trusted to destroy the infection of typhoid fever, cholera, or the micrococci of suppuration. The action of soap solutions is much influenced by the temperature, which is easy to understand when we recall the powerful action of hot water alone upon bacterial life.

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[*] "Zeitschr. f. Hygiene," Bd. IX, 1890, p. 414.

[†] "Archiv f. Hygiene," XLIII, 1899, p. 369.

Therefore soaps alone cannot be depended upon for the certain disinfection of objects and clothing, but in solution with hot water as usually applied, and especially in conjunction with certain compatible chemicals, and also with the mechanical cleansing which almost always accompanies their application, this substance has a wide and varied usefulness.

Soap solutions should always be made with a soft water. The addition of one of the caustic alkalies, as lye, increases its germicidal and detergent value. The solution should be strong, containing not less than 10 per cent. of soap, and the water should be as hot as possible and applied with mops or brushes so as to aid the solvent action of the substance upon the oleaginous and albuminous matter clinging to dirty surfaces or fabrics.

Medicated soaps are for the most part a snare and a delusion so far as any increased germicidal action is concerned; in fact, the addition of carbolic acid, bichlorid of mercury, and other substances which have the property of combining with the soap, seems actually to diminish the disinfecting value of that substance. As a rule a very small quantity of the disinfecting substance is added to the soap, and when it is called to mind what an exceedingly small quantity of soap is necessary for the ordinary washing of the skin, and the further dilution of this small amount by the water used, it is easy to understand that medicated soaps, as ordinarily applied, cannot have an energetic disinfecting action.

An exception seems to be the soap devised by McClintock,* in which the mercury salt exists unchanged and active. He found that the double iodid of mercury answers these purposes in the proportion of 0.5 to 2.0 per cent. A solution containing 1 per cent. of the soap was found by him to be fatal for pus cocci, cholera, diphtheria, and typhoid fever bacilli in one minute. The soap does not attack nickel, silver, aluminium, steel instruments, or lead pipes, and does not coagulate albumin.

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* "Disinfection and Disinfectants," London, 1898, p. 347. Quoted by Harrington.

CHAPTER IV.

INSECTICIDES APPLIED TO DISINFECTION AGAINST THE INSECT-BORNE DISEASES.

Arsenic—Petroleum—Bisulphid of Carbon—Pyrethrum—Sulphur—Formaldehyd Gas—Hydrocyanic Acid Gas—Danyz' Virus and Other Rat Poisons.

Practically all the germicidal agents are also insecticides. There are some exceptions to this statement, notably formaldehyd, which is one of our most potent germicides, but has little or no effect upon insect life.

As the fly, mosquito, flea and other insects are known or suspected of conveying the infection of some of the communicable diseases, it is important that the disinfector know how best to destroy this class of vermin. The general subject of protecting the individual against the bites, dangers and annoyances of mosquitos, flies, etc., and the subject of ridding a community of this dangerous class of vermin, although a very important one from an economic and hygienic standpoint, cannot be discussed in the limits of these pages. These questions belong more to the sanitarian than to the disinfector. Only those agents are considered which are useful to the disinfector in exterminating vermin in a room or building, in order to prevent the spread of disease.

The mosquito is known to transmit the infection of several diseases. This insect is the intermediate host for the parasites of malaria, yellow fever and filariasis. The micro-organisms are taken into the stomach of the mosquito with the blood it sucks. From the stomach the parasites pass into the general body cavity or the glands of the mosquito, and are extruded again through the insect's proboscis under the skin of its victim. That is to say, the mosquito inoculates the infectious principles into the system just as we would experimentally inoculate an animal by means of a hypodermic syringe.

On the contrary, the fly, ant, flea and other insects transmit the infection of disease in quite another way. For instance, flies spread the infection of typhoid fever, cholera, plague and anthrax smeared upon their legs and upon the external surfaces of their bodies. This is readily understood when we recall the habit of flies feeding upon and breeding in decomposed meat, dejecta and other matters apt to contain the infectious principles of the above-named diseases.

The investigation of the Army Medical Commission during the Spanish-American war practically established the fact that the fly is an important factor in the dissemination of typhoid fever.

Victor Vaughan, a member of that commission, stated that flies undoubtedly served as carriers of typhoid infection, giving the following as reasons for his belief: "They swarmed over fecal matter in the latrines. They visited and fed on food prepared for the soldiers in the mess tents. In some instances, when lime had been recently sprinkled over the contents of latrines, flies with their feet whitened with lime were seen walking over the food. Officers, whose mess tents were protected by means of screens, suffered less proportionately from typhoid fever than those whose tents were not so protected. Typhoid fever gradually disappeared in the fall of 1898, with the approach of cold weather and the consequent disabling of the fly."

It is perfectly easy to understand how a fly, alighting upon the skin of a smallpox patient, and contaminating its legs, proboscis and body with the fluid exudate from the vesicles and pustules, may carry this highly infectious material to other persons in the same house or to neighboring houses.

Flies, fleas, ants and other insects spread the infectious principles of many communicable diseases in another way than simply this mechanical conveyance of the bacteria upon their external parts. These insects feed upon organic matter containing the infective principles, which live a variable length of time in their intestinal canals, and the live and virulent micro-organisms are deposited with the dejecta. In this way infection is transmitted from infected materials to man, from animals to man, and from man to man.

It is believed that the biting insects, such as flies, fleas, ants, etc., do not inoculate the parasites under the skin when they bite. When this does occur, it is probably due to an accidental contamination of the mouth or biting parts of the insect with the infective germs. In other words, the transference seems to be mechanical. The insect does not act as an intermediate host, and the bacteria do not pass through various phases of development in the insect, as is the case with the malarial parasite and the mosquito.

The flies, fleas, ants, etc., deposit the infectious material on the skin with their excrement, and in other ways. The virulent infection is rubbed into the little wounds or scratched into the skin as a result of the irritation caused by the bites, thereby setting up the disease.

For the reason that plague is transmitted through the agency of rats, a paragraph is introduced upon the means commonly employed to destroy these rodents.

ARSENIC.

The arsenical compounds, according to Marlatt,* have supplanted practically all other substances as a food poison for biting insects. The two arsenicals in most common use and obtainable everywhere are Paris green and London purple. Scheele's green and arsenite of copper are less known and less easily obtainable, but in some respects are better than the first-mentioned poisons, as will be shown later. The use of powdered white arsenic is not recommended on account of its corrosive action, as well as the fact that it is apt to be mistaken for harmless substances.

Paris green is a definite chemical compound of arsenic, copper, and acetic acid (known as the aceto-arsenite of copper), and should have a nearly uniform composition. It is a rather coarse powder, or, more properly speaking, crystal, and settles rapidly in water, which is its greatest fault so far as the making of suspensions of this substance is concerned. The cost of Paris green is about 20 cents per pound.

Scheele's green is similar to Paris green in color and differs from it only in lacking acetic acid; in other words, it is simply arsenite of copper. It is a finer powder than Paris green, and therefore is more easily kept in suspension, and has the additional advantage of costing only half as much per pound.

London purple is a waste product in the manufacture of anilin dyes, and contains a number of substances, chief among which are arsenic and lime. It is quite variable in the amount of arsenic it contains and therefore is not so effective as the green poisons. It comes in a fine powder and is more easily kept in suspension than Paris green. It costs about 10 cents a pound.

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* Farmers' Bulletin No. 19, "Important Insecticides," by C. L. Marlatt, 1898, U. S. Dept. of Agriculture.

Arsenite of lead is prepared by combining, approximately, 3 parts of the arsenite of soda with 7 parts of the acetate of lead (white sugar of lead) in water. These substances, when pulverized, unite readily and form a white precipitate, which is more easily kept suspended in water than any of the other arsenical poisons. Bought wholesale the acetate of lead costs about 7½ cents a pound, and the arsenite of soda costs about 7 cents a pound. Its use is advised where excessive strengths are desirable and upon delicate plants where otherwise scalding is likely to result.

The arsenical poisons may be applied in one of three ways: (1) in suspension, as poisoned waters, mainly in the form of sprays; (2) as a dry powder blown or dusted about the infested areas; or (3) as poisoned bait.

It must be remembered that the arsenicals are very poisonous, and should be so labeled, and care taken to prevent accidents.

An average of one pound of either Paris green, Scheele's green, or London purple to 150 gallons of water is a good strength for general purposes in using the wet method. The powder should first be made up into a thin paste in a small quantity of water, and if the suspension is to be used upon plants, vegetables, or about foliage, an equal amount of quicklime should be added to take up the free arsenic and remove or lessen the danger of scalding.

For the distribution of dry poison the arsenicals are diluted with 10 parts of flour, lime, or dry gypsum.

PETROLEUM. Petroleum, kerosene or coal oil is a very valuable insecticide, but of limited application, as it must be used in liquid form, its vapor being too inflammable for consideration in this connection.

As a remedy for mosquitos kerosene has proved very effective when applied as recommended by L. O. Howard. It is employed to destroy the larvæ of the mosquitos in pools, still ponds, stagnant water, water buckets, and other small collections of water not of value for their fish. In large bodies of water it is not nearly so effective, as the oil is blown about by the wind, thereby uncovering the greater portion of the surface. An apparatus devised by Dr. Doty is of use in distributing the petroleum over the surface of ponds. It consists of a wooden framework carrying the oil pipes which deliver the petroleum through many small openings projecting 6 inches or so below the surface of the water. The float is drawn over the pool while the petroleum is allowed to escape, thus coating the entire surface, and emulsifying some of the oil with the water, which intensifies its insecticidal action.

The petroleum is applied at the rate of 1 ounce to 15 square feet of water surface. It forms a uniform film over the surface and destroys all forms of aquatic insect life, including the larvæ of the mosquito and the adult females coming to the water to lay their eggs. The oil must be renewed every few weeks, depending upon the temperature and other circumstances. A light grade of fuel oil is recommended by Howard for this purpose.

Petroleum is also useful against roaches, bedbugs, and other forms of insect vermin when used by direct application or by spraying either in the form of the pure oil or as an emulsion with water, soap, or milk.

BISULPHID OF CARBON. Bisulphid of carbon (CS_2) is a very efficient insecticide, but a dangerous one on account of its inflammable and explosive nature. When pure it is a mobile, colorless liquid, with an agreeable ethereal odor; but often it has a more or less fetid odor from the presence of other volatile compounds. The liquid must be kept in well-stoppered bottles, in a cool place away from the light and fire. It evaporates very rapidly at the ordinary temperatures, so that in using this substance in a confined space it is sufficient to pour it into open pans and it will quickly pass into the air as a gas, in which state it is an efficient insecticide. It is very inflammable—more so than ether—and burns with a pale blue flame, yielding sulphur dioxid and carbon dioxid or monoxid.

Upon the authority of Howard and Marlatt,* this substance, distributed about a pantry or room in open vessels, will evaporate and if used in sufficient quantity will destroy roaches and other vermin. Unless the room can be very tightly sealed, however, the vapor dissipates so rapidly that its effects will be lost before the roaches are killed.

In the use of this substance every precaution must be taken to see that there is no fire, lighted cigar, etc., in or about the premises during the treatment, on account of its inflammable and explosive nature. It is also deadly to the higher animals, so that apartments should be thoroughly aired after its use.

According to Hinds,† shallow tin pans or plates make good evaporating dishes for carbon bisulphid. The larger the evaporating area, the better. There should be about one square foot of evaporating surface to every twenty-five square feet of floor area, and each square foot of evaporating surface should receive from one-half to one pound of liquid. These figures are, of course, only suggestive and approximate. Pans should be placed as high in the room as possible, since the vapor is so heavy that it settles most heavily to the lower parts. Care should be taken, when placing the pans, to see that they are nearly level, so as to hold the liquid, though ordinarily no particular harm will be done if some of it is spilled. It should not be found necessary to lose time in adjusting such things after the application is begun.

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* "The Principal Household Insects of the United States," Bulletin No. 4, new series, revised edition, U. S. Dept. of Agriculture, 1896.

† Farmers' Bulletin No. 145, U. S. Dept. of Agriculture, "Carbon Bisulphid as an Insecticide," by W. E. Hinds, 1902.

If there are special places which are difficult of access or treatment with the pans, cotton waste, bundles of rags, or the like may be saturated and thrown into these places.

Everything should be done to avoid unnecessary delays and to facilitate the rapid exposure of the liquid. If the liquid is bought in large quantities, smaller receptacles may have to be provided for transferring it to the pans.

PYRETHRUM.

Pyrethrum is a popular and much used insecticide because it is comparatively cheap and non-poisonous to the higher animals, but unfortunately it is not very powerful for the destruction of roaches, ants, mosquitos, bedbugs, fleas, flies, etc.

Pyrethrum, also sold under the names of Buhach and Persian insect powder, or simply insect powder, is the flowers of the Chrysanthemum roseum and the Chrysanthemum carneum, both hardy perennials and resembling chamomile in appearance.

According to Kalbrunner,* 4 grains of the pure powder sprinkled on a fly in a vial should stupefy it in one minute and kill it in two or three minutes. This is used as a test for the strength of pyrethrum.

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* U. S. Disp., p. 1334.

It acts on insects externally through their breathing pores, and according to Marlatt,* is fatal to many forms of biting and sucking insects, being chiefly valuable against household pests, such as roaches, flies, and ants.

It is used either as a dry powder or by its burning fumes. As a dry powder it may be used pure or mixed with flour, in which form it should be puffed about the room, especially into the cracks. Against mosquitos the powder should be burned in the room, and if used in sufficient strength and for a sufficient length of time, it will kill many of these insects, but it cannot be depended upon for the destruction of mosquitos infected with yellow fever, for some of the insects are only stupefied. They must be gathered up and destroyed after the fumigation.

The regulations of the United States army require the burning of five pounds of the pyrethrum powder for each 1000 cubic feet of air space, for the destruction of mosquitos in confined spaces.

SULPHUR.

Sulphur is one of the most valuable insecticides we possess. It may be used in several forms.

Sulphur dioxid gas produced and used according to the methods given for bacterial disinfection will kill roaches, bedbugs, mosquitos, flies, fleas, and all kinds of vermin, including rats and mice. This substance is therefore exceedingly useful in disinfecting for such diseases as plague, yellow fever, malaria, and insect-borne infections.

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* "Important Insecticides," Farmers' Bulletin No. 127, p. 15.

The methods of producing the gas by burning sulphur, or by liberating the liquefied sulphur dioxid, the time of exposure, and all important directions concerning the application of this substance to practical disinfection will be found on page 118. The time of exposure necessary to kill insects and vermin is shorter than that given for sulphur dioxid as a germicide. One hour is ample for mosquitos, and two hours for rats.

Very dilute atmospheres of the gas will quickly kill mosquitos. It is quite as efficacious for this purpose when dry as when moist, whereas the dry gas has practically no power against bacteria. Contrary to formaldehyd, it has surprising powers of penetrating through clothing and fabrics, killing the mosquitos, even when hidden under eight layers of toweling, in one hour's time and with very dilute proportions.

This substance, which has so long been disparaged as a disinfectant because it fails to kill spores, must now be considered as holding the first rank in disinfection against insect-borne diseases.

The *flowers of sulphur* is very efficient in its powdered state as an insecticide. It may be applied in several forms, the simplest of which is to merely sprinkle the dry sulphur about the places where the insects are found. The flowers of sulphur may also be advantageously combined with other insecticides, such as kerosene emulsion, resin wash, or a soap wash, mixing it first into a paste and then adding it to the spray tank in the proportion of from 1 to 2 pounds to 50 gallons.

The sulphur in its dry form must be directly applied to the places where the insects are found, and is used more for the destruction of the mites and rust of plants and fruit. It has but a limited use against bedbugs, ants, roaches, etc., and is practically useless against the winged insects.

Bisulphid of lime is a good liquid insecticide where a liquid is applicable. It may be very cheaply prepared by boiling together for an hour or more, in a small quantity of water, equal parts of the flowers of sulphur and stone lime. A convenient quantity is prepared by taking 5 pounds of sulphur and 5 pounds of lime, and boiling in 3 or 4 gallons of water until the ingredients combine, forming a brownish liquid. This may be diluted to make 100 gallons of spray.

FORMALDEHYD GAS.

Formaldehyd gas, while holding the front rank as a germicide, is a feeble insecticide. It seems to have no effect whatever upon roaches, bedbugs, and insects of this class, even after prolonged exposure to very high percentages of the gas. While very irritating, this substance is not toxic for the higher forms of animal life. (See page 87.)

Mosquitos * may live in a very weak atmosphere of the gas overnight. It will kill them, however, if it is brought in direct contact in the strength and time prescribed for bacterial disinfection. For this purpose any of the accepted methods for evolving the gas is applicable, but the methods which liberate a large volume in a short time are more certain than the slower ones.

Direct contact between the insects and the gas is much more difficult to obtain in ordinary room disinfection against mosquitos than against germs, because the sense of self-protection helps the former to escape from the effects of the irritating gas. They hide in the folds of towels, bedding, clothing, hangings, fabrics, and out-of-the-way places where the formaldehyd gas does not penetrate in sufficient strength to kill them. The gas is polymerized and deposited as paraform in the meshes of fabrics, which prevents its penetration, and large quantities are lost by being absorbed by the organic matter of fabrics, especially woolens. In our tests, whenever the insects were given favorable hiding-places, such as in crumpled paper or in toweling, they quickly took advantage of the best place for themselves and often escaped destruction.

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* "Disinfection against Mosquitos," Rosenau, Laboratory Bulletin No. 6, Marine Hospital Service.

There is a striking analogy between the strength of the gas and the time of exposure necessary to penetrate the fabrics in order to kill mosquitos, and the strength and time necessary to penetrate in order to kill the spores of bacteria.

Mosquitos have a lively instinct in finding cracks or chinks where fresh air may be entering the room, or where the gas is so diluted that they escape destruction. They are able to escape through incredibly small openings. Some of the smaller varieties, such as the Stegomyia fasciata, can get through a wire screen having twelve meshes to the inch. Therefore, formaldehyd gas cannot be trusted to kill all the mosquitos in a room which cannot be tightly sealed.

It is concluded that to succeed in killing all the mosquitos in a closed space with formaldehyd gas, the following definite requirements are essential: A very large volume of the gas must be liberated quickly, so that it may diffuse to all portions of the space in sufficient concentration. The room must have all the cracks and chinks where the insects may breathe the fresh air carefully sealed by pasting strips of paper over them. The room must not contain heavy folds of drapery, clothing, bedding, or fabrics in heaps, or so disposed that the insects may hide away from the full effects of the gas.

For the methods of evolving formaldehyd gas, the quantities to be used, and other details of the process, see Chapter II.

HYDROCYANIC ACID GAS.

Hydrocyanic gas is extremely poisonous to all forms of life. It kills roaches, bedbugs, mosquitos, fleas, flies, rats, and mice with great certainty and very quickly. It is much less poisonous to the vegetable forms of life, as has been discussed under the use of this gas as a germicide (page 137). The gas is much used in greenhouses for the destruction of insect pests, and for the scale insects and other parasites of fruit trees.

Hydrocyanic acid gas has a distinct place in the disinfection of granaries, stables, ships, barns, outhouses, and other uninhabited structures infested with vermin. But it should not be used in the household, or any other inhabited building, as the least carelessness with it would probably mean the loss of human life.

For the methods of evolving the gas and other details see page 138.

THE DESTRUCTION OF RATS ON ACCOUNT OF PLAGUE.

The ordinary methods of catching rats by such means as cats, dogs, ferrets, traps, poisoned bait, etc., are all useful in ridding a locality of this rodent.

In Glasgow, Japan, and other places where plague prevailed as an epidemic, thousands of rats, many of them infected with plague, were caught and disposed of, by the authorities offering a price upon their heads. Experience has shown that this reward must not be too large, else persons will breed the rodents as a paying investment.

While the extermination of the rats in a city or a community of considerable size may be a hopeless undertaking, their destruction on board an infected ship, in a stable, granary, or other limited area, is quite possible, although it takes time, care, and much patience.

The handling and final disposition of rats suffering with or dead of plague is a matter requiring special care in order to guard against the infection. According to Simond, the fleas transmit the infection from the rats to man. He states that the flea will not leave the rat for man as long as the body of the rat is warm. Therefore, in the handling of rats, whether dead or alive, the hands should be protected with gloves and other precautions taken to guard against the fleas.

The bodies of the dead rats should be cremated at once, and all surfaces exposed to the infection disinfected with a bichlorid solution or carbolic acid.

The rats on board a ship or in a confined structure may best be destroyed by sulphur fumigation. Careful search must be made for the dead bodies. This same substance is useful in destroying or in driving the rats out of a sewer, in fighting the infection of plague in municipalities. For this purpose the sulphur is burned in the sulphur furnace and the fumes are driven into the sewer by a centrifugal fan. (See page 127.)

Rats may also be killed in a confined space by the use of other poisonous gases, such as hydrocyanic acid gas, carbon bisulphid, or even carbon dioxid. Formaldehyd gas cannot be trusted to destroy these animals.

The methods of using hydrocyanic acid and carbon bisulphid have been given in another portion of this chapter. The carbon dioxid is evolved by simply burning charcoal in open fires, and taking care to close the room or hold of the vessel very tightly.

The substance known as Danyz' virus is sometimes useful in helping to rid a locality of these rodents. This virus consists of a culture of a bacillus belonging to the para colon group. It appears to be identical with Bacillus typhi murium of Loeffler.

This organism is naturally pathogenic for mice, in which rodents it sometimes produces spontaneous epizootics. Its virulence has been raised and specialized by artificial means in the laboratory, so that it has become fatal for rats by ingestion. This artificial virulence is not very stable: It may be maintained under special conditions a few months, but the virulence is apt to fall off, especially on exposure to light and air.

So far as rats are concerned, the effect depends somewhat on the amount ingested. Large amounts are frankly fatal. Small quantities are uncertain. Rats that survive the ingestion of the virus are rendered immune. Such rats may eat large amounts of the virulent virus with no untoward effect.

The infection caused in rats by eating the virus has feeble power of propagating itself from rat to rat. It, therefore, cannot produce a widespread epizootic among these rodents. In practical use it must be spread around so that as many of the rats as possible will eat it.

In many respects it resembles a chemical poison, with this great advantage, viz., that it is harmless, so far as known, to man and domestic animals. It has the great disadvantage that chemical poisons do not possess, of rendering the animals immune by the ingestion of amounts that are insufficient to kill, or by the ingestion of cultures that have lost a little of their virulence.

In my experiments I succeeded in killing less than half the number (46 out of 115) of rats fed. The conditions in a cage are so much more favorable for the fatal action of the virus than could possibly be the case in nature that it is safe to assert that a less number would succumb in a wild state.

The virus may, therefore, be used as one of the means in the fight against rats, but it is far from being a sure means of exterminating these rodents in a particular place.

CHAPTER V.

DISINFECTION OF HOUSES, SHIPS, AND OBJECTS.

The following objects, arranged alphabetically, are those commonly requiring treatment by the disinfector, and a brief outline of the special methods applicable to each object is given. The principles involved and the details of the methods are given in full in other portions of the book and are not repeated in this chapter.

Air.

It is quite impossible to disinfect the air of a room during its occupancy by the patient. Any of the known volatile substances in sufficient concentration to kill the micro-organisms would make life unbearable. It is therefore absurd to place such substances as carbolic acid, chlorinated lime, or formalin in an open pan in the sick-room or the water-closet, with the idea that they are serving a useful purpose in disinfecting the atmosphere or in preventing the spread of infection.

The infection of few, if any, of the communicable diseases is given off in the exhaled breath. The exhaled breath is always sterile no matter how many microbes may be contained in the inhaled air. That is, the process of respiration acts as a bacterial filter for the atmosphere. When the air becomes infected, it is usually in an indirect way. From smallpox and the exanthemata the infection is given off into the air from the patient mainly in the fine particles of epidermis that float about the compartment with the dust. From tuberculosis and diphtheria the infection may float into the air from the dried sputum.

The atmosphere surrounding the patient may also become contaminated with the germs of tuberculosis, diphtheria, the pneumonic form of plague, and other diseases in which the infection is discharged from the body in the expectoration, by coughing, sneezing, speaking, etc. In these explosive expiratory movements, a fine spray is thrown several feet from the mouth, and may be carried with the currents of the air to all portions of the room.

The infection of some diseases is carried in the air, in the bodies of mosquitos, or on the bodies of flies, instead, as was formerly supposed, as a miasm or poison directly vitiating the atmosphere. Malaria, which means bad air, is the type of these so-called "miasmatic diseases." From this we may infer that fly screens and mosquito netting are more important in many sick-rooms than germicidal agents, as far as the dissemination of such infections through the air is concerned.

In the cases where the infection is liable to contaminate the surrounding air, a thorough ventilation of the sick-room should be maintained. The infection disposed of in this way is generally lost by dilution, or killed by the sun. There is nothing equal to the open fireplace for the ventilation and purification of the air of the sick-room, for by this method the infection is not only carried away, but is destroyed by the heat of the fire in exit.

Proper precautions must be taken at the bedside to prevent the infection leaving the body in a live and virulent form. These precautions differ for each class of infections and have been described under each disease in Chapter VI.

The hanging of sheets wet with bichlorid of mercury or some disinfecting solution at the doorway serves a useful purpose in arresting some of the infection that may be floating in the air, and thus limiting its dispersion. It must, however, be remembered that sheets, while serving a useful purpose, are not an absolute guarantee, for they dry out very quickly and it is difficult to make the sheet close the opening so that there will be no air currents around the edges, especially if the doorway is used for persons passing in and out.

When a room has been badly infected and the air of the room is suspected, it should always be given a preliminary fumigation with one of the gases, which will diminish the probability of the infection spreading through the air, and will protect the operators who have to take up the carpets, or prepare the bedding and the other contents of the room for steaming or other process.

Ambulances. See Carriages.

Ballast. See Vessels.

Bandages, Gauze, etc.

Bandages, gauze, etc., may be sterilized by boiling, steaming, or dry heat, in any of the apparatus described under these processes.

Bed Linen, Body Linen, etc.

Articles of this character should always be disinfected after contact with any of the communicable diseases, for they are very apt to be infected. This may readily be done by boiling, by steaming, or by immersion in one of the ordinary germicidal solutions.

Care must be taken in boiling or steaming woolen underclothing, because of their liability to shrink.

Special care is necessary in washing and disinfecting towels, sheets, underwear, and the like that are soiled with discharges, such as pus, blood, or excreta. If such articles are heated or boiled without special precautions being first taken, they will become indelibly stained, by the coagulation of the albuminous matter which becomes fixed in the fiber.

In Germany, wash that is soiled is treated by the following process:* It is wrapped in a sheet wet with sublimate solution, and this placed in a sack likewise moistened with a germicidal liquid. The sack is placed unopened in a solution containing 3 per cent. of soft soap and heated to 50° C. for three hours, and left in the same solution forty-eight hours after it cools. If not soiled with albuminous matter the wash is immersed in a solution of bichlorid of mercury 1 : 2000, with the addition of common salt. After this preliminary disinfection, the articles are boiled half an hour in a water containing:

Petroleum,	10 gm.
Soft soap,	250 gm.
Water,	30 liters.

A simpler method is to disinfect the fabrics containing the stains in a 5 per cent. solution of formalin for two hours and then remove and wash in the usual way.

BEDS. Wooden and iron beds may be effectively disinfected by a mechanical cleansing with a hot disinfecting solution, such as bichlorid of mercury or carbolic acid. Care must be exercised not to overlook any of the joints or cracks, especially in wooden beds, which should be taken apart.

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* Levy and Klemperer, "Klinische Bakter.," p. 434, Berlin, 1898.

A careful search should be made for bedbugs, which must be destroyed by use of the insecticide agents mentioned in Chapter IV.

BEDDING. Mattresses and pillows are among the most difficult objects to disinfect, on account of the deep penetration required. It is very important that they be thoroughly disinfected throughout their mass on account of the very intimate contact with the patient and the likelihood of their being deeply soiled with infected discharges. Therefore, nothing but steam should be trusted to render these objects safe.

BULBS. See Food.

BRUSHES. Good brushes can be boiled or steamed without injury, and this is the best method of disinfecting them. If boiled in a solution containing soap, soda, borax, or one of the alkalies, the brush may be more readily cleansed of the collection of oleaginous matter and epithelial débris that collect about the bristles.

Brushes made of poor bristles or with glued backs are injured by boiling. Such brushes must be mechanically cleansed in a soap or alkaline solution, and then soaked for an hour in corrosive sublimate 1 : 1000, or carbolic acid 5 per cent. A 3 to 5 per cent. solution of formalin will also answer. Or the brush may be cleansed and disinfected at the same time by mechanical washing in a 1 per cent. solution of tricresol or lysol. The ordinary exposure to formaldehyd gas cannot be trusted to render a brush safe.

It is well known how difficult it is to sterilize brushes for use in the operating room. It is the best surgical practice to start with a new brush, which is thoroughly boiled each time and kept in one of the germicidal solutions.

Brushes in hotels, public toilet rooms, railroad coaches, and other places, where they are used promiscuously by many persons, should be disinfected periodically to prevent them conveying ringworm and other skin infections. Brushes used by the barber should always be disinfected after using them on any customer having a diseased scalp, and they should be disinfected at the end of each day's work as a routine precaution.

BOOKS. With the exception of their external surfaces, books cannot be disinfected in the bookcases or on the shelves of houses and libraries. However, if the books have not been handled or exposed to infection in any way except by their presence in the sick-room, there is no reason to consider any part of the book except the exposed surface infected. Such books may be rendered safe by exposing them to formaldehyd gas without first disturbing the books in any way.

Books which have been handled by the patient, or which have been otherwise exposed to infection, require particular care in their disinfection, on account of the difficulty of penetrating with any germicidal substance between the leaves.

Books may be satisfactorily disinfected in a specially constructed chamber or in any small air-tight space, by means of formaldehyd gas. They must be arranged to stand as widely open as possible upon perforated wire trays. Under these conditions the exposure should be continued twelve hours in the special chamber, with high percentages of formaldehyd and a temperature of 80° C., a partial vacuum having first been produced. The binding, illustrations, and print of books are not injured by this process. See page 110.

When only a few books are to be treated, in the absence of special apparatus they may be disinfected by dropping two or three drops of a 40 per cent. formalin solution on every second page, taking care to distribute the drops well. The book is then laid in a tight box or drawer in which more formalin has been sprinkled, and left in a warm place not less than twenty-four hours.

Pamphlets and unbound volumes may be steamed without serious harm. Steam is not applicable to the disinfection of bound books on account of the glue and leather.

CADAVERS.

Dead bodies may be the source of spreading many of the communicable diseases. The body, without previous washing, should be wrapped in a sheet wet with a strong germicidal solution, such as bichlorid of mercury 1 : 1000, carbolic acid 5 per cent., or tricresol 1 per cent., until it is disposed of. Should it be desirable to wash the body, it should be done with formalin or Labarraque's solution, or one of the solutions mentioned above.

From a sanitary standpoint bodies dead of one of the communicable diseases are best disposed of by burning. When cremation is not practicable, the body should be surrounded by twice its weight of freshly burned lime in a tight coffin, and buried at least six feet underground. This treatment is effective in preventing the spread of cholera, typhoid fever, plague, smallpox, diphtheria, and most diseases to which man is liable.

Embalming with the strong solutions of formalin and arsenic that are commonly used for this purpose is effective in destroying all but the surface infection of bodies dead of the communicable diseases.

The disinfection of carcasses dead of anthrax is a very important and difficult matter, and has been discussed in detail in the article on Anthrax in Chapter VI.

CAPS. See Hats.

CARGO. See Vessels.

CARRIAGES, AMBULANCES, CARS, ETC.

Carriages, ambulances, wagons, cars, etc., may be disinfected by having built a small tight structure in which they are inclosed and then surrounded with formaldehyd gas. Such a building is used for the disinfection of ambulances in New York city. By using high percentages of formaldehyd such conveyances may be given a satisfactory surface disinfection in an hour. This method would be particularly applicable to street cars, and the railroad coach, cabs, and other public conveyances, where time is an important factor.

Of course, if the vehicle has been used for the transportation of a communicable disease, the cushions, lap robes, curtains, floor carpet, upholstery, and similar articles must be removed for steaming, immersion in one of the germicidal solutions, or for treatment according to the method given for its particular class, especially if the patient has soiled the interior of the coach with discharges.

The treatment of vehicles does not differ in any way from the disinfection of rooms or other similar objects, and may be accomplished by a thorough drenching with a hose or a mechanical cleansing of the surface with any one of the ordinary germicidal solutions. See also Railroad Cars.

CISTERNS. See Wells.

CLOTHING.

Clothing may be disinfected by a great variety of methods. They may be boiled, steamed, soaked in disinfecting solutions, or exposed to dry heat or the action of gases.

Of all the methods steam is the most reliable, but it has the disadvantage of shrinking some woolen goods, or creasing them and setting them out of shape. Good clothing and fine fabrics may be steamed without appreciable injury if they are exposed to steam under pressure, so managed that condensation and undue wetting are avoided, and provided that the articles are hung or loosely laid in the steam chamber so that they do not come in contact with any metal parts, and finally, provided that, as soon as the steaming is completed, the articles are immediately removed and stretched and shaken in the air until they are cooled and dried.

The combination of high percentages of formaldehyd gas with dry heat in a partial vacuum is a splendid method for the disinfection of clothing, fabrics, and baggage on a large scale. The method is rapid, has sufficient power to penetrate heavy fabrics, and is not injurious.

Clothing may be disinfected by formaldehyd gas in a room or inclosure by any of the methods given for the evolution of that gas. Proper care must be taken to so arrange the clothing that the gas may have free access to all the surfaces, and the exposure should be not less than twenty-four hours to insure penetration. Formaldehyd gas by this method should not be trusted to disinfect quilted wraps or heavily lined overcoats and similar articles requiring deep penetration.

Boiling and immersion, while very efficient, are limited to the disinfection of the simpler and cheaper articles of clothing.

COLORS. Care must be taken not to injure colors in the process of disinfection. Many of the cheap prints run when wet, and such should not be disinfected by boiling, immersion in disinfecting solutions, or by steaming. In steam disinfection objects are sometimes soiled by being in contact with other articles dyed with soluble colors, and this possibility must always be guarded against in loading the chamber. (See page 74.)

Sulphur dioxid is very ruinous in this respect. It bleaches practically all the vegetable and anilin dyes. It is very apt to discolor white lead paint (oxid of lead), by the formation of the black lead sulphid. It does not attack white zinc paint when dry.

Formaldehyd gas has practically no effect upon colors. It can be used to disinfect an oil painting, water-color, or pastel. It does not affect the coloring matter of fabrics, excepting occasionally the delicate lavenders.

Chlorin is a very active bleaching agent, and acts injuriously upon almost all the pigments commonly used in the arts. Chlorinated lime, the hypochlorites, and Labarraque's solution likewise affect colors, on account of the chlorin liberated by their decomposition.

Oxygen, ozone, and hydrogen peroxid are also very powerful bleaching agents.

Solutions of the mercury salts, of carbolic acid and the cresols, or formalin, have little special action upon pigments commonly used in the arts.

CURTAINS. See Draperies.

CARPETS. Carpets and rugs are very apt to become infected with almost any of the communicable diseases, and they are troublesome to handle properly. In cases where they have become soiled with the infected discharges, or where gross carelessness has prevailed in the sick-room, they should be subjected to a preliminary exposure to one of the gaseous disinfectants, then carefully taken up, wrapped in a sheet wet with bichlorid of mercury, and removed for steaming. Stains due to organic matter, such as blood, sputum, and excreta, must be removed before the steaming, else they will become fixed. After the steaming they may be given a mechanical cleansing and hung up in the sunshine for several days.

Carpets that have been exposed in the sick-room where proper precautions have been taken at the bedside to prevent the spreading of the contagium, may be safely treated without taking them up, although this is always preferable. The carpet may be disinfected in place by wetting it with a 5 per cent. solution of formalin, and keeping the room closed not less than twenty-four hours, or by exposing the carpet to the action of formaldehyd gas in full strength for twenty-four hours.

Carpets that have become infected by the spilling of discharges, etc., should have the contaminated area immediately saturated in a strong solution of formalin. Carpets in rooms that are being given a general disinfection with formaldehyd gas may be sprinkled or mopped with formalin just before the room is closed and the gas evolved.

COTTON.

Cotton and cotton fabrics may be boiled, steamed, subjected to dry heat at 150° C. for one hour, exposed to formaldehyd gas, or immersed in any of the ordinary disinfecting solutions without appreciable injury.

Sulphur dioxid not only bleaches the cotton, but rots the fiber, owing to the action of the sulphurous acid which is formed by the gas in the presence of moisture and oxygen, and is therefore not applicable.

COMBS.

Combs may readily be rendered safe by soaking in formalin, carbolic acid, or bichlorid solutions, after which they may be mechanically cleansed. The rubber and celluloid of which combs are now made will not, as a rule, stand boiling, steaming, or dry heat.

DRAPERIES, HANGINGS, CURTAINS.

As a rule these furnishings of a room do not come in contact with the patient or his discharges, and therefore may be disinfected by formaldehyd gas while the room itself is being treated.

In case these articles are contaminated so that they need more than a surface disinfection, they should be steamed, in accordance with the plan laid down for the handling of carpets or immersed in one of the germicidal solutions.

The sick-room should not contain draperies, hangings, or other unnecessary articles of this character, and it is always advisable to remove them, as well as the carpets before the possibility of contamination.

EXCRETA.

Lime in one of its forms is best suited for the disinfection of the excreta, in any quantity. For small amounts, formalin, carbolic acid, or one of its derivatives, as tricresol, lysol, saprol, is efficient.

In hospitals the infected discharges are sometimes boiled in an appropriate vessel, with the addition of a deodorizing substance, as potassium permanganate.

Whatever chemical substance is used, some of it should be placed in the vessel that is to receive the dejecta, and more is added afterward and the mass thoroughly mixed. Let the mixture stand a sufficient length of time,—not less than an hour,—depending upon the strength and nature of the disinfectant. In estimating the amount of disinfectant required for the disinfection of excreta in camps, quarantine stations, etc., count upon an average of 400 grams of solid excrement per person per day, and 1500 to 2000 c.c. of urine.

Excreta must always be so protected that it will not become a breeding and feeding-place for flies and other insects, which are prolific ways of spreading cholera, typhoid fever, and perhaps other diseases.

Milk of lime is a very cheap and efficient disinfectant for excreta. As officially prescribed for this purpose in the army of the United States, it is prepared by the addition of 1 per cent. by weight of the freshly slaked lime to 8 parts of water.

In its application to fecal matter the milk of lime is employed in the proportion of 5 per cent. by bulk, with a daily addition equal to 10 per cent. by bulk, of the estimated increment of feces. According to this method, to each 95 parts of feces there is added 0.62 part of water-slaked lime, or 1 part in 153. According to Munson, this seems a very small proportion for a substance of no very powerful germicidal properties, particularly in the absence of thorough mixing with the infectious material, or with the deterioration of the lime through atmospheric influence, which is so liable to occur.

In view of the cheapness of quicklime, and to avoid any possible failure in the attainment of disinfection, it will do no harm to err on the side of safety and considerably increase the strength or quantity of the milk of lime as prescribed above.

The perfunctory sprinkling of infectious matter with weak milk of lime, as is often done, is a procedure worse than useless. Lime has but slight effect upon odors and requires a long time to accomplish disinfection.

Lime should not be thrown into the hoppers of water-closets, for the disinfection of the dejecta, without dilution, for otherwise the thick mass may accumulate and obstruct the pipes.

In disinfecting the excreta with lime the reaction of the resulting mixture must be alkaline, else the object will not be attained (Phuhl).

Lime, or the milk of lime, is very useful for the disinfection of privies, or trenches in camp, or in country practice. For its use under these circumstances the amount required may be arrived at as follows: The amount of fecal matter per person is reckoned at 400 grams a day. If the urine is also to be disinfected this may be counted as 1500 to 2000 c.c. per person daily. For the disinfection of the solid excrement alone, 5 grams of lime, or 40 c.c. of the milk of lime (1 to 8), must be reckoned for each person per day. If the urine is included it will take four to five times as much. The mixture must have an alkaline reaction.

Chlorinated lime is a powerful deodorant, vigorously attacking the gaseous effluvia of putrefaction, and is a useful disinfecting agent for excreta. A solution of good chlorinated lime in water in the strength of ½ to 1 per cent. by weight has been shown to disinfect typhoid and cholera stools in ten minutes, while a 1 per cent. solution will destroy anthrax bacilli in two hours. Thoroughly mixing the chlorinated lime with the fecal matter to be disinfected is essential.

In the United States army a 4 per cent. strength of chlorinated lime in solution is officially prescribed for use in the disinfection of the excreta of the sick, it being specifically stated that the chlorinated lime so used should be of good quality and not have undergone deterioration.

Formalin ranks high among the list of germicidal agents useful for the disinfection of the dejecta: It penetrates deeply and is not hindered in its action by the albuminous matter present. Enough should be added so as to make 5 per cent. of the mass and be thoroughly incorporated. The vessel must be kept tightly closed at least an hour. As a deodorant it acts almost instantly.

Carbolic acid in 5 per cent. solution added to a similar bulk of excreta cannot be depended upon to render the latter sterile in one hour. It can, however, be used for the disinfection of infected stools, such as cholera, typhoid, etc., taking care to mix well and let stand at least one hour.

Tricresol, *lysol*, and *saprol* are valuable agents for the disinfection of fecal matter in small amounts, on account of their energetic action, and because their efficiency is not impaired by the presence of albuminous matter. Sufficient quantities of these phenol derivatives must be added so as to be present in 2 per cent. of the entire mass, and thoroughly incorporated. Carbolic acid and its derivatives are more expensive than lime and without any special advantages.

Ferrous sulphate is very extensively used for the disinfection of excreta, but its germicidal powers are too weak to recommend it for this purpose. It is claimed also to have deodorant properties, which are denied by Foote.

In using this salt of iron it is essential to add it to the fecal matter in solution in great excess on account of its feeble germicidal powers. If the contents of the latrine are semi-fluid it is best to add a concentrated solution. Munson recommends 5 parts of the iron salt to each hundred parts of the total contents of the latrine vault as essential to efficiency. In the French army ferrous sulphate is used in

10 per cent. solution, and it is officially laid down that at least 250 c.c. of such a solution should be used per day for each person using the latrine.

Dry earth promotes the desiccation of excreta, thus preventing putrefactive changes while absorbing the odors. It has no inherent germicidal or antiseptic qualities, but is a useful means of disposing of dejecta in camps and country places when lime and chemicals are not at hand. A better method under these circumstances is to burn the dejecta upon an improvised fire.

Corrosive sublimate is totally unfitted for the disinfection of excreta, because it coagulates the albuminous matter with which it combines, and therefore lacks penetration; nor does it destroy the bad odors.

FECES. See Excreta.

FOOD. The ordinary methods of cooking are, as a rule, sufficient to render meats and vegetables safe from the danger of conveying infection. The food must be well cooked throughout and must afterward be guarded against contamination by dust, by flies and other insects, by handling with infected hands, or by contact with infected dishes.

The remnants of food or drink that have formed part of the patient's meal should be burned or boiled,—particularly if the case is one of diphtheria, tuberculosis, cholera, pneumonia, plague pneumonia, or any of the exanthematous diseases in which the food is apt to become infected by handling or by contact with the secretions of the mouth.

In districts where cholera and typhoid fever or epidemic dysentery prevail, raw foods, such as salads, celery, tomatoes, and fruits, may be disinfected by half an hour's immersion in a 3 per cent. solution of tartaric acid and afterward washed in boiled water.

There is plenty of evidence now to prove that parasitic and infectious diseases may be spread through the consumption of uncooked vegetables, even where pestilential diseases do not prevail in epidemic form. G. Ceresole * found ameba, threadworms, eggs of tenia, oxyuris, anchylostomum, and a great variety of bacteria upon lettuce, endive, radishes, celery, and the like.

Roots, bulbs, fruits, and other articles of food may be given an efficient surface disinfection by immersing them in a 5 per cent. solution of formalin. This is sometimes required for food products of this nature coming from plague- or cholera-infected regions. This treatment does not harm the food value of these articles and is not poisonous.

FLOORS.

The floors should always be given careful attention because they are especially likely to be infected. The sputum of tuberculous cases, of pneumonia, diphtheria, etc., too frequently finds lodgment upon the floor. The plague bacillus has been found in the dust and dirt of the floor.

The floor may best be disinfected by a soaking or by a mechanical cleansing with any one of the strong disinfecting solutions, such as bichlorid of mercury 1 : 1000, carbolic acid 5 per cent., tricresol 1 per cent., etc.

Bichlorid of mercury should not be used for the disinfection of the "dirt floors" frequently found in the Orient and also in the poorer hovels of our own country. Carbolic acid, or one of its derivatives, is more trustworthy for this purpose, as its action is not hindered by the presence of albuminous matter.

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* "Il Policlinico," 1900–1901, p. 55.

FURNITURE. Ordinary furniture, such as chairs, tables, desks, bureaus, cabinets, sideboards, etc., made of wood, with hard polished surfaces, may be effectively disinfected with formaldehyd gas or sulphur dioxid, according to any of the methods given for evolving these gases. All the drawers and doors should be opened so as to expose all portions to the action of the gas.

Furniture may also be disinfected by mechanical cleansing with any of the disinfecting solutions, taking care not to overlook any surface and to get the solution into all the cracks and crevices.

Upholstered furniture is one of the bugbears of the disinfector, on account of its bulk, its value, and the deep penetration sometimes required. If the upholstery is leather, oil-cloth, or other impervious material, it may be treated with one of the germicidal liquids, care being taken to get well into all the puckered tucks of the cushions. If the article is covered with a tapestry or other pervious fabric, the only efficient way of rendering it safe is by soaking the cushions through and through with a 5 per cent. solution of formalin and leaving the furniture in an inclosed space twenty-four hours. Fortunately, this treatment does no special injury to fine fabrics.

Upholstered furniture which has simply stood in a house or room in which a case of infectious disease has occurred, and which has in no way come in contact with the patient or the infectious materials, may be considered as being infected merely upon the surface, and therefore may with perfect safety be treated by gaseous disinfection. It is always well, in using formaldehyd, which is practically the only gas applicable for these objects, to sprinkle or wipe the surfaces of the upholstery with a 5 per cent. solution of formalin just before closing the room preparatory to liberating the gas.

GAUZE. See Bandages.

GLASSWARE. Glassware, porcelain, china dishes, and the like may be disinfected by boiling, steaming, or immersion in any one of the disinfecting solutions.

HANDS. The hands should be thoroughly washed and disinfected after contact with infected material of any kind. It is very difficult to disinfect the skin, especially around the finger nails, so that a cursory immersion into a bichlorid solution will not suffice. After contact with the skin of a case of smallpox or one of the exanthematous diseases, or after contamination with the discharges of cholera or typhoid fever, the hands should be immersed in a hot 1 : 1000 bichlorid solution, then given a very thorough cleaning with soap and water, using a nail brush. After this the hands should be immersed in a 1 : 1000 bichlorid solution for three minutes.

In surgical practice the following methods of disinfecting the hands are commonly employed:

Fürbringer's method: The hands are actively scrubbed one minute with soap and water as hot as can be borne, then they are rubbed for a minute with 80 per cent. alcohol, and finally washed in a 0.5 per cent. sublimate solution. As modified and generally used this method consists of washing the hands in soap and hot water for five minutes, using the nail brush. They are then soaked in alcohol for one minute and scrubbed with a sterile brush. They are finally soaked in a 1 : 1000 bichlorid of mercury solution for three minutes.

The *method of Schatz*, as modified by Kelley, is as follows: The hands are first vigorously washed with common brown kitchen soap or green soap and hot water for five minutes.

The hands thus mechanically cleaned and softened are next immersed in a hot saturated solution of potassium permanganate until stained a deep mahogany color. They are then immersed at once in a hot saturated solution of oxalic acid, which decolorizes and completely sterilizes them. The oxalic acid is then removed by warm water or sterilized lime-water.

HANGINGS. See Draperies.

HATS AND CAPS. Hats and caps cannot be steamed because they usually contain sizing (glue) and leather. They may be carefully wiped with or immersed in one of the disinfecting solutions, preferably formalin, and then hung up to dry so that they will not lose their shape. Or they may be exposed for twenty-four hours to formaldehyd gas in sufficient concentration. Straw hats without trimmings may be exposed without injury to sulphur dioxid, as that gas is used in their manufacture to bleach them.

HIDES. See Leather.

HOLDS OF VESSELS. See Vessels.

HOUSES. The disinfection of houses resolves itself into the disinfection of its rooms (*vide* Rooms). As a rule it is better, in disinfecting an entire house with a gas, to treat each room or suite of rooms separately, and finally to fumigate the halls and stair wells.

The disinfection of the entire house is rarely required. The infection of most diseases may be confined to the sick-chamber and the adjoining rooms; but if the patient has contaminated most of the rooms of the house before the nature of affection is recognized, or if, on account of carelessness or other reasons, the infection is not confined, the entire house will need treatment. In this case it is best to begin with the upper stories and work downward, arranging so that all the rooms and halls of the house will be exposed to the disinfecting agent simultaneously; where that is not possible, the upper stories of the house should be finished and locked so that they may not be used until the rest of the house is finished.

INSTRUMENTS, SURGICAL.

Surgical instruments may be disinfected by many methods, but they are best sterilized by the method of Schimmelbush;* *i. e.*, after careful cleaning they are boiled in a 1 per cent. solution of sodium bicarbonate for fifteen minutes or longer. This does not rust steel and does not dull the cutting edge.

LEATHER, HIDES, SKINS, FUR, ETC.

Leather, hides, skins, and fur are ruined by boiling or steaming. They may be treated by immersion in one of the germicidal solutions. Leather which has not received a surface dressing is rendered hard and brittle by wetting, and should therefore be disinfected by one of the gases.

Formalin "fixes" leather by combining with its albuminous constituents, rendering it brittle, and should therefore not be used for this substance.

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* "Arbeiten a. d. chir. Klinik d. k. Univ. Berlin," 5. Theil, 1891, S. 46 *et seq.*

LETTERS. See Mail.

LINEN. Flax or linen fabrics may be boiled, steamed, or disinfected by immersion in any one of the ordinary chemical solutions used for this purpose. It may also be subjected to formaldehyd gas without appreciable harm. Sulphur dioxid rots linen fiber as it does cotton, and bleaches dyes, and should therefore be avoided.

LITHOGRAPHS. See Pictures.

MAIL. First class letter mail has been accused of spreading smallpox, measles, scarlet fever, and diseases of the desquamating class. There is little danger of letters spreading the infection of such diseases as plague, cholera, typhoid fever, tuberculosis, and the great majority of the communicable diseases. However, the disinfector is often called upon to disinfect the mail as a matter of precaution.

There are several methods by which the letter mail may be treated. One of the best ways for large quantities is to expose the letters to high percentages of formaldehyd gas, with dry heat in a partial vacuum (see page 110). This method has the advantages of being quick and not requiring the puncturing or opening of the envelopes, it being sufficient to lay the letters loosely on end on the racks. The only special precaution necessary in this method is to eliminate the letters with wax seals, for this substance softens at the temperature of 80° C., which is the degree of heat necessary to obtain trustworthy results. The method presupposes the installation of expensive apparatus and the presence of a skilled attendant.

A very simple method, which I practised with success in Havana upon large amounts ot letter mail, and which takes very little time, consists of the following procedure: One person clips the corner of the envelopes with a sharp scissors, and passes them on to the next person, who drops three or four drops of formalin into each letter, by means of an eye dropper. The envelopes are then placed in the sack, which has been liberally sprinkled with formalin, and more formalin is sprinkled between every few layers of letters as they are placed loosely in the sack. Use a fine spray, which will not wet the ink sufficiently to make it run. The sack is filled in successive layers and then tightly closed and laid in a warm place for no less than six hours—preferably overnight. Or it may proceed immediately on its journey, provided the sack is not opened until the proper time has elapsed. Very large quantities of mail matter may be disinfected in this manner in a surprisingly short time.

This method is also particularly applicable to hospitals, lazarettos, quarantine stations, and similar places where only a few letters need treatment each day. In these cases the following procedure will be found useful and perfectly safe: The mail is collected every evening at a stated time, and each letter is treated inside and out with formalin as described above. The letters are placed in a tight box made especially for this purpose, and laid away overnight in a warm place. In the morning the box is carbolized upon the outside and taken to the picket line or quarantine limits, where the mail is taken out by the guard and, after a little preliminary airing, transferred to a clean receptacle and is ready for the post-office.

Sacks of mail which have been treated by this method should not be opened in a closed room, for the smell of the formaldehyd is very unpleasant. This may be obviated by opening the bags out of doors and letting them air half an hour, or by sprinkling some ammonia about.

If the letters are exposed to formaldehyd gas evolved by one of the methods used for room disinfection they must be arranged so that all the surfaces of the envelopes are freely exposed to the action of the gas, and left twenty-four hours if the envelopes are not punctured, six to twelve hours if the envelopes are punctured.

Sulphur dioxid cannot penetrate paper nearly so well as formaldehyd, and therefore it is necessary to puncture the envelopes if they are to be disinfected by this gas. In puncturing envelopes for this purpose care must be exercised to use an instrument that will actually cut out a little circle of the paper, for if the letter is simply punctured with a sharp-pointed instrument the hole made seals itself from the interior of the envelope.

In the absence of other means letters may be subjected to dry heat, either in special apparatus or in the kitchen oven.

MATTRESSES. See Bedding.

MILK.

Of all foods milk is the most likely to be infected. It is a very good culture medium for almost all the pathogenic bacteria; for instance, fresh milk contaminated with a few typhoid, diphtheria, cholera, or plague bacilli will in a few hours at ordinary temperatures have every drop teeming with many of these organisms without appreciably altering the appearance of the milk. It is easy to understand how readily the infection of typhoid fever, cholera, diphtheria, or plague may get into the milk. The exanthematous diseases have frequently been traced to the milk-supply. The possibility of tuberculosis being conveyed in the milk is ever present. The milk-supply of a large city is always under suspicion, so frequently does it carry disease, and it is therefore fortunate that we have simple and sure methods of rendering it safe.

Milk may best be disinfected by boiling or Pasteurization.

Boiling coagulates the casein and renders the milk less palatable, and more difficult to digest for some persons, though it makes it absolutely safe so far as the destruction of infection is concerned.

Pasteurization consists in heating the milk to a temperature of from 70° to 75° C. (about 180° F.) for half an hour and then chilling it quickly and keeping it cool until used. This degree of heat is sufficient to kill all the non-spore-bearing bacteria, such as tuberculosis, typhoid, cholera, dysentery, diphtheria, and, in fact, practically all the infectious agents of the epidemic diseases to which man is liable. As the spores and some of the hardier saprophytes are not killed by this degree of heat, it is important to chill the milk quickly, for if allowed to cool slowly the continued warm temperature favors the growth and multiplication of these forms of bacteria, which, although they do not cause disease directly, give rise to toxins or chemical poisons in the milk which cause indigestion or very severe symptoms of poisoning.

MONEY.

Money may convey the infection of the communicable diseases, especially smallpox and the exanthemata.

Metallic money may best be treated by immersion in a solution of carbolic acid 3 per cent., of formalin 3 to 5 per cent. Boiling water, steam, or dry heat is also applicable to the disinfection of specie.

Paper money may be disinfected by sprinkling the notes with formalin, taking care to sprinkle the solution in small drops and upon the face of each bill, then placing in a tight box in a warm place for six hours.

The disinfection of currency does not differ from that of letter mail. (See page 212.)

MUSICAL INSTRUMENTS. The stringed instruments may be disinfected by formaldehyd gas. The brass wind instruments may be boiled, or, if they have keys, may preferably be disinfected by a careful washing with formalin or carbolic acid solution; or they may be subjected to formaldehyd gas. The wood-wind instruments and the mouth-pieces of the reed instruments may be treated with formaldehyd gas, or, better still, immersion in a strong formalin solution.

THE PATIENT. The patient is, of course, the source of almost all the infection with which we have to deal, and therefore the greatest care should be taken to prevent the contagion leaving the body in a live and virulent form.

The methods of disinfecting the skin, the various discharges, the bedding, and other objects which come in contact with the patient have been enumerated under separate headings.

In all cases of the communicable diseases scrupulous cleanliness of the patient, his bed and bedding must be exercised. The patient's skin may be bathed with one of the disinfecting agents in weak dilutions, and must always be kept clean with soap and water, or alcohol, depending upon circumstances.

In the exanthemata the skin should be anointed with vaselin or a bland oil, to which a little carbolic acid may be added. This will largely prevent the contamination of the surroundings with the infection which leaves the body in the desquamating epiderm.

In the case of cholera, typhoid fever, and the intestinal diseases, the buttocks must be kept clean and the napkins used for this purpose should be moistened with a solution of bichlorid of mercury or carbolic acid, and immediately after being used placed in a strong germicidal solution, boiled, or, better, burned.

The sick-room should be kept freely ventilated, and the patient protected from the annoyance of flies and mosquitos. In the case of malaria, yellow fever, and other diseases conveyed through the agency of insects, fly screens and mosquito bars must be used and the greatest care taken to destroy any insects that may gain entrance into the room.

Special measures to prevent the spread of the infection from the patient are given under each one of the communicable diseases in Chapter VI, and need not be repeated here.

PICTURES AND PAINTINGS. Formaldehyd gas does not injuriously affect photographs, lithographs, prints in black and white or colors, oil paintings, water-colors, or pastels, and is practically the only method applicable to the disinfection of these articles.

PIGMENTS. See Colors.

PILLOWS. See Bedding.

RAGS. Rags may be disinfected by any of the methods applicable for fabrics; but as they are especially apt to be contaminated with the discharges and other infectious materials, they therefore require treatment with methods which penetrate deeply—or better still, methods which sterilize, such as steam, boiling, or immersion in one of the stronger germicidal solutions.

It is quite impossible to disinfect a bale of rags, prepared under great pressure for shipment. No disinfecting agent could penetrate such a firm mass. It is therefore necessary to unbale and expose all portions of the contents of the mass freely to the action of whatever disinfecting agent is used. At ports where large quantities of rags are shipped it is advisable to have a special car constructed, having racks upon which the rags are spread out for exposure to steam under pressure.

RAILROAD CARS.

The principles of disinfection as applied to railroad cars present nothing novel. The application of these principles varies somewhat with the kind of car we have to deal with.

Flat cars, or open cars, seldom need disinfection, for even should they become infected the constant exposure to the sun and weather is usually sufficient to render them safe from the danger of conveying disease. They may readily be disinfected, whenever that may be necessary, by scrubbing or flushing them with carbolic acid, or bichlorid of mercury solutions.

Freight cars, or box cars, seldom need disinfection. In the case of the insect-borne diseases, the destruction of the mosquitos and flies which such cars are very apt to harbor is necessary. Freight cars are best treated for this purpose by fumigation with sulphur dioxid, which at the same time destroys bacterial infection upon the surface. The outside of the car rarely needs any attention.

If the freight car is infected with any of the exanthemata or diphtheria, cholera, or other bacterial infections it may be disinfected with formaldehyd gas, or, better still, by washing or flushing with one of the usual germicidal solutions, and then left open to air and dry, preferably in the sunshine. In actual practice it will sometimes be found useful to disinfect these cars by steam from the locomotive.

Cattle cars and cars used to transport live stock need special attention, particularly if anthrax, tetanus, glanders, or tuberculosis is the disease with which they are contaminated. The disinfection of cars of this type is so much like the disinfection of a stable that it is unnecessary to repeat the process here. (See page 229.)

Day coaches and parlor cars: The disinfection of the ordinary passenger coach presents no special difficulty. The day coach is nothing more nor less than a room on wheels, and all the principles for the treatment of rooms apply with equal force to these cars. If the disinfection is done as a precautionary measure (which should be required at stated intervals), it is sufficient to follow a thorough mechanical cleansing, with formaldehyd gas. The carpets and rugs and all similar articles, including the upholstered seats and back rests, if removable, should be taken from the car and given a mechanical cleansing in the open and exposed to the sunshine. The spittoons and the floors of the car are especially liable to become infected; the floors may be mopped or scrubbed with one of the germicidal solutions, and the contents of the spittoons may be disposed of in one of the ways mentioned under the heading Sputum. The cuspidors themselves should be steamed or well rinsed in a carbolic acid bath.

If the disinfection is done on account of the known contamination with one of the communicable diseases, it is treated exactly as a room would be under like conditions.

The railroad coach is very likely to harbor mosquitos, flies, and other insect pests that may carry disease. For this reason precautions will have to be taken, on cars leaving districts infected with yellow fever, malaria, plague, etc., to keep these insects off the cars; or measures will have to be taken to destroy them after they get on board. As both of these requirements are difficult, if not impossible, to carry out with certainty, it will be found best to have relays, and to change cars upon leaving an infected for a non-infected but infectible area.

Sleeping cars present a greater danger than any other rolling stock. The berths are very apt to become infected with tuberculosis, diphtheria, and any one of the exanthemata, especially as they are kept closed—almost hermetically sealed—against the fresh air and sunshine during the day. Much of the difficulty encountered in the disinfection of the sleeping car is due to peculiarities in construction, such as the compact manner in which the bedding is stowed away, the heavy and unnecessary carpets and hangings, the excessive molding and ornamentation which catch the dust and hold the infection, the use of such materials as plush for the upholstery, the vile arrangement of the open-hopper water-closet, the absence of faucets arranged so as to wash in running water instead of a bowl used also for the teeth cleaning and other processes, the absence of any system of ventilation, and the like. A sleeping car is nothing more nor less than a bedroom on wheels, and all the methods described for the treatment of such rooms (see page 222) are applicable.

Before attempting to disinfect the interior of a sleeping or other passenger coach with a gas, it is important to close the deck sashes and all the ventilator openings for the Pintsch gas flames. Much gas will be lost through the open hopper of the water-closet unless that is tamponed. Some cars have a system of ventilating ducts, the fresh air entering under the seat, or somewhere near the bottom of the car, which must all be carefully sealed against leakage.

Formaldehyd gas is practically the only one of the gaseous disinfectants which may be used for the treatment of the sleeping car. As this gas lacks the power of penetration, all the berths must be opened and all the bedding and other fabrics should be removed for steaming or other treatment, as it is practically impossible to arrange all the bedding and fabrics in the small space of a car so that every surface will be freely exposed to the full effects of the gas.

After the removal from the car of the bedding, hangings, carpets, and other fabrics, the toilet room should be given special attention The drinking glasses, the bowls and slabs of the wash-stands, the brushes and combs, the seat of the water-closet, and other objects should be washed or immersed in one of the germicidal solutions suitable to each class. A 3 to 5 per cent. solution of formalin, or a 5 per cent. solution of carbolic acid, or a 1 per cent. solution of tricresol or lysol is especially applicable to this disinfection. Bichlorid cannot be used on account of its corrosive action, especially upon the metal parts.

After all this preliminary treatment the car may then be subjected to the formaldehyd gas, care having been exercised that all the openings are well sealed, as described above.

It may well be understood that the method for the routine disinfection of the sleeping car, while presenting no particular difficulties, do not satisfy the requirements of modern activities. Railroad managers demand germicides which are instantaneous in their action, non-destructive in their effects, all-pervading in their power of penetration, so that no disarrangement of the contents of the car would be necessary, and so that the disinfection could be accomplished without loss of time and with little cost. Further, the disinfecting agent used must leave no unpleasant odor or other disagreeable effects to offend the sensitiveness of the passengers. Such ideal methods are not known. It takes time and money to effectively eradicate the infection from so complicated a structure as a sleeping car, and when the traveling public are more thoroughly informed upon the dangers that menace them, they will require a very thorough purification of the sleeping coach periodically as a necessary precautionary measure.

ROOMS.

The disinfection of the living room calls for all the resources of the disinfector's art. The fact that it is necessary to bring the apparatus and materials to the room in order to disinfect it with most of its contents is one of the main difficulties and will call forth the ingenuity as well as the vigilance of the operator.

A room cannot be effectively disinfected while it is occupied. Any gaseous substance in sufficient concentration to destroy bacteria would make life unbearable. Under these circumstances the best that can be done is to wash all exposed surfaces with one of the germicidal solutions, and to observe the strictest cleanliness about the patient, the bed and bedding, and to promptly disinfect and dispose of the discharges, etc. It is absurd to keep a pan of carbolic acid, formalin, chlorinated lime, or any other substance under the sick-bed or in the water-closet with the hope that it will in any way purify the air and prevent the spread of the disease. Occasionally a deodorant about the room may be used with advantage, but where proper cleanliness and ventilation are observed, such substances are rarely called for.

It is, of course, of prime importance to prevent the infection of the room, by taking the precautions required for the particular disease in question, but we are now dealing with the destruction of infection and not its prevention.

The method to be employed for the disinfection of a room will vary somewhat with the disease for which the disinfection is done. As a rule one of the gases is to be preferred for the group of exanthemata, because the infected particles are apt to fly about and lodge in places inaccessible to the other methods. In the case of malaria, yellow fever, and filariasis the destruction of the mosquitos must be given our first consideration. In disinfecting rooms for plague our efforts must be directed against the rats, mice, and fleas, as well as to the destruction of the plague bacillus. For cholera and typhoid fever we must pay particular attention to the water and food. In routine work in the treatment of rooms liable to be infected with a variety of diseases, and disinfected as a precautionary matter, formaldehyd gas is the most generally useful agent we possess.

Certain articles commonly found in living rooms, such as bedding, carpets, rugs, cuspidors, upholstered furniture, and other articles deeply infected or difficult of disinfection, must be treated separately as described for each article.

In case the room is so constructed that it is impracticable to disinfect it with a gas, it must be treated in accordance with the methods given *seriatim* for its walls, floors, and all its contents.

Preparation of a Room for Gaseous Disinfection.—After closing the doors and windows, paste strips of paper over the cracks and crevices, or calk them with towels, waste, and the like. (See illustration, page 85.) Be particular to close the hot-air register, and to properly close all ventilators, fireplaces, and other openings. Open closets and small doors, and expose all the drawers, lockers, and similar places, so that the gas may have free access to remote corners. Furniture should be moved away from the walls, so that there may be a free exposure of surfaces. Curtains and hangings should hang loosely, so that nothing may keep the gas from gaining free access to every portion of the fabrics. Clothing, bedding, and articles of this character should be suspended on lines in a clear portion of the room, and not too far from the place where the gas is evolved, in order that they may have the full benefit of the undiluted effects of the disinfecting agent at a point where the gas is more concentrated and where the more energetic currents favor penetration.

In thus arranging a room it is very important to expose to the gas the same surfaces that were exposed to the infection. It may therefore be mistaken zeal to disturb the contents of the room too much; besides, the too vigorous shaking up of the dust or infectious matter may be the means of spreading the disease.

Ordinarily, carpets and rugs should be left in place, and after the fumigation they may be taken up and hung in the sun for a day or two, and pounded or otherwise mechanically cleaned. If the carpets and rugs have been infected with the discharges or badly contaminated in other ways, the particular spots should be thoroughly saturated with a strong solution of formalin or other strong disinfectant. Then, after the preliminary fumigation, the rugs and carpets should be removed for steaming and sunning. Bedding, towels, and other articles of like nature may be left to the action of the gas, afterward removed for boiling or steaming, or immersion in one of the disinfecting solutions. Whenever articles are removed from the room for disinfection they must be wrapped in a sheet wet with one of the germicidal solutions. Bichlorid of mercury is particularly appropriate for this purpose. The gases cannot be depended upon to exert their disinfecting influence very deeply; therefore any article which there is reason to believe is deeply or badly infected should be removed for other treatment, depending upon its character. Rubbish that may be gathered up in the room should be burned. The cuspidors and their contents require special treatment, and any other article which the gases cannot be depended upon to disinfect thoroughly must be removed and disinfected according to its nature.

After the room has been properly prepared, all is made tight and the room filled with the gas according to the methods given, and it should then be sealed in such a way that it cannot be opened without the knowledge of the disinfector. After the proper time has elapsed the room should be opened by the disinfector himself, and the operation should not be considered successful unless there is a distinct smell of the gas present. The windows and doors are then opened so that the gas may be allowed to blow away, or neutralized according to the methods given.

A room which has been carefully treated as above outlined may be considered disinfected and will need no other treatment to render it safe. However, it is always advisable to follow the disinfecting processes with a very thorough mechanical cleansing and a good sunning and airing.

When a room is to be disinfected by another method than one of the gaseous disinfectants, a somewhat different procedure is followed. Article after article is removed piecemeal and disinfected by appropriate methods. After the room is emptied, the walls and other surfaces are flushed with bichlorid of mercury 1 : 1000 or one of the other germicidal solutions in equivalent strength.

ROOTS. See Food.

RUBBER. Rubber is injured by dry heat. Pure rubber may be boiled or subjected to steam under pressure without injury. Articles made of impure rubber, such as mackintoshes, rubber shoes and boots, rubber sheeting, vulcanized rubber articles, and the like, are ruined by boiling or steaming, and must be disinfected by immersion in one of the germicidal solutions.

Rubber nipples of nursing bottles, after mechanical cleansing, should be boiled in an alkaline solution, containing a little borax or baking soda, and then washed in boiled water.

RUGS. See Carpets.

SHIPS. See Vessels.

SILKS. Silk seldom needs disinfection, and fortunately so, for it is difficult to treat without injuring the fabric or color. Formaldehyd gas does not injure the fiber and has no effect upon the great majority of colors; but the delicate lavenders of anilin origin are sometimes slightly modified in tint, after exposure to this gas.

While steam does not harm the silk fiber appreciably, it ruins the fabric, so that this method of disinfection is totally inapplicable.

SKIN. See Hands.

SKINS. See Leather.

SPUTUM. The sputum, not alone of the sick, but of the well also, is often laden with the infection of disease, especially pneumonia, pulmonary tuberculosis, diphtheria, plague, and other affections of the air passages.

Infection is spread by means of the sputum, especially when it dries and is disseminated by the air currents. Another fruitful method of spreading diseases, the infection of which is found in the sputum, is by the act of kissing; also by using spoons, forks, cups, etc., which have been in the mouth of the sick or those whose sputum is infected, and shortly afterward used without being disinfected. There is still another way in which the sputum contaminates the air and the surface of objects—viz., in coughing, sneezing, speaking, and other acts of an explosive expiratory character the sputum is sprayed into the air often to a considerable distance, even a couple of yards from the mouth, and the air currents will carry the minute droplets to all parts of a room.

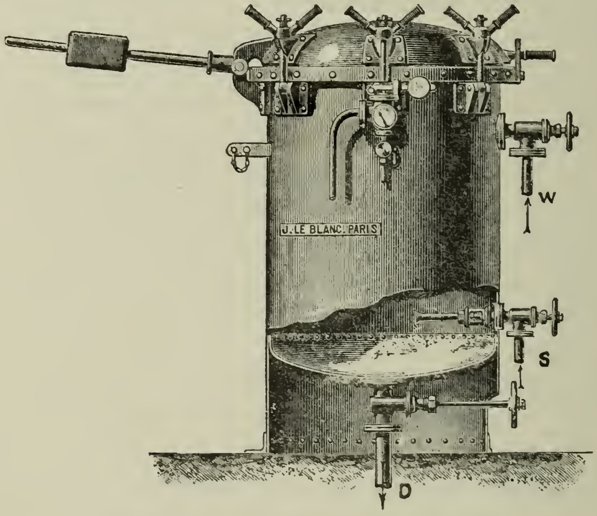
The sputum should be kept well covered until it is disposed of. Simply keeping water in the bedside cups or in the cuspidors will prevent the danger of the dissemination of infection through the agency of dried sputum, though an antiseptic solution is to be preferred for this purpose.

The best way to disinfect sputum is by heat. A small quantity may be placed directly upon the fire and burned up; the same method is also most suitable for the handkerchiefs and other articles that have been used to hold the expectoration.

Next to burning, boiling or steaming is the safest method of treating infected sputum. The boiling may be accomplished in any appropriate vessel, and the steaming may be done in either streaming steam or in the autoclave under pressure. In hospitals and in private houses this method is recommended, care being taken not to heat the ordinary glass or glazed earthenware cuspidors too suddenly for fear of breaking them.

The disinfection of sputum is difficult to accomplish with the chemical solutions, on account of its dense consistency and tenacious character, which hinder penetration. Bichlorid of mercury solutions are entirely inapplicable to the disinfection of this material. The bichlorid coagulates the albuminous matter of the sputum and thereby prevents penetration, and by uniting with the albuminous substances it is used up and rendered inert so far as its disinfecting powers are concerned.

FIG. 53.



AUTOCLAVE FOR DISINFECTING SPUTUM.

Carbolic acid in 5 per cent. solution may be used for the disinfection of sputum, but it cannot be considered trustworthy because it coagulates the albuminoid matter, though not so energetically as bichlorid of mercury. Tricresol or lysol in 2 per cent. solutions is well suited for this purpose, or formalin in 3 to 5 per cent. solution, these substances to be used in generous amounts and to be well incorporated and to remain in contact with the infected sputum no less than one hour.

A very good apparatus for the disinfection and disposal of the sputum of hospitals, sanatoria, etc., consists of an autoclave in which the material is steamed under pressure and at a temperature of 120° C. The steam is admitted through the pipe S, Fig. 53, and after the completion of the process the disinfected mass is washed through the drain D into the sewer by water entering the autoclave at W.

STABLES. The disinfection of a stable requires a very thorough application of all the resources at the hand of the disinfector. The conditions met with in a stable render its disinfection doubly hard, not only on account of the accumulation of organic filth, which has worked into the many crevices and saturated the woodwork, but on account of the high resistance of the anthrax and tetanus spores, for which stables are sometimes disinfected. In addition to these diseases, stables require disinfection on account of tuberculosis, glanders, pleuropneumonia, and various diseases of man as well as those of the domestic animals.

It is advisable to give the stable a preliminary fumigation, preferably with sulphur, in order to destroy surface infection and the vermin which always infest these places. The preliminary disinfection is especially important in the case of plague, glanders, tuberculosis, or any of the exanthematous diseases, not only to prevent the spread of the infection, but as a safeguard for the disinfectors. Then remove all small articles that need disinfection. The blankets should be wrapped in moist bichlorid sheets and boiled, steamed, or burned. Buckets, curry-combs, brushes, stall tools, and other equipment that has been in contact with the sick animals or with infectious materials, should be mechanically cleaned with hot carbolic solution, in which they may be allowed to soak over night. Metallic and wooden objects or utensils should be given a thorough preliminary cleansing with a stiff brush and hot water and soap, and then boiled or immersed in a 5 per cent. solution of carbolic acid or 2 per cent. solution of tricresol for several hours. Leather articles, as harness or equipment, should receive a similar preliminary cleansing and be scrubbed with either a strong solution of bichlorid of mercury or carbolic acid.

All hay and grain should be removed from the racks and mangers, and all bedding from the floors. After its careful collection at some designated point this refuse should be saturated with petroleum and destroyed by fire.

The stable must now be soaked with a strong antiseptic solution applied with a hose, or splashed on all surfaces by means of mops. The floors, corners, and stalls must be saturated with the solution. On account of the presence of so much albuminous matter, phenol or one of its derivatives is preferred for this purpose to sublimate solutions. Now scrape out the débris from all the cracks in the floors and walls; collect it for burning. Then clean the woodwork with hot lye or a strong alkaline soap solution, and follow with another general hosing with the antiseptic liquid.

After several days' exposure to air and sunshine the interior of the stable should receive a fresh coat of whitewash, applied thickly, and prepared from lime freshly burned shortly before the time of use.

The watering troughs are very apt to be infected, especially in dealing with glanders. In all instances, not only the troughs and watering buckets should be disinfected, but the water remaining in them, for often there is no drain or sewer, and this water poured on the ground may be a source of subsequent infection. The water may first be disinfected by the addition of a suitable amount of any of the ordinary soluble germicides. The troughs are then to be mechanically cleaned, thoroughly removing all organic matter, and then applying a strong germicidal solution to both the inside and the outside. For metal-lined troughs the use of bichlorid of mercury is, of course, inapplicable, and for such carbolic acid, tricresol, formalin, or potassium permanganate is recommended. Most antiseptics are poisonous and must, therefore, be finally washed out of the trough or buckets by flushing with fresh water and then airing in the sunlight before they are again used. Strong carbolic solution or formalin should be poured down all pipes and drains.

Sometimes the ground in the immediate vicinity of the stable will need some attention; lime will generally be found most useful for this purpose. Carcasses and excreta are to be disinfected and disposed of according to the methods given under these titles.

TABLEWARE. Great care must be exercised in disinfecting knives, forks, spoons, and dishes used by patients suffering from communicable diseases. Cholera, typhoid, tuberculosis, pneumonia, diphtheria, plague, and the exanthemata may be conveyed by inattention to this precaution. Tableware is most readily disinfected by scalding.

TENTAGE. It is seldom necessary to burn tents after exposure to any infectious disease, for they may be effectively disinfected by any of the following methods:

The tent is emptied of all its movable contents, each object being disinfected in accordance with methods appropriate for it. The canvas is then thoroughly wetted from the inside with a 5 per cent. solution of formalin or carbolic acid or a 1 : 1000 solution of corrosive sublimate. The solution may be applied with mops, brooms, or with a hand pump. The lower portion of the canvas walls, together with the sod-cloth, and the tent poles and flooring, should receive a particularly thorough wetting. Ordinarily the sunshine is a sufficient disinfectant for the outside of the tent.

Another method, more difficult of application, but more thorough than the preceding, is to strike the tent; lay the canvas flat on the ground and scrub or saturate it with the hot disinfecting solutions mentioned above, preferably formalin, which does not rot the canvas. Rinse well with clear water and allow to dry in the sunshine. Tents that can be tightly closed may be disinfected by a gas. In this case it is necessary to use a large excess of the gas and a longer exposure on account of the inevitable waste. Sulphur dioxid will rot the fibers of the canvas; formaldehyd is therefore preferable. The tent, its poles, and floor should be exposed to the sunlight for several days and thoroughly dried before again being used. It is generally preferable to pitch the tent on fresh, uninfected ground. If that is not practicable, the space should be given a good sunning and may be liberally sprinkled with lime before the tent floor is again laid, or if the ground has been contaminated with discharges, it may be saturated with a germicidal solution.

URINE. The urine is generally disinfected with the dejecta (see Excreta). It should always be disinfected in the case of cholera, typhoid fever, and most of the communicable diseases, by adding sufficient carbolic acid to make a 5 per cent. solution, of bichlorid of mercury to make a 1 : 1000 solution, or formalin sufficient to be present in the proportion of 3 to 5 per cent.

Vessels. The disinfection of a vessel does not differ materially from the disinfection of houses and rooms. It should not, however, be attempted by one not familiar with the intricacies of marine architecture, for many special conditions are met with on board ship that are very different from those found on shore.

While the principles of disinfection as applied to vessels present nothing unusual, the application of these principles calls for much ingenuity and the keenest vigilance upon the part of the disinfector.

It is important to enlist the sympathies of those on board with the necessity for the disinfection, for the successful accomplishment of the purification of the vessel may be materially helped by the cheerful cooperation of the passengers and crew, otherwise the difficulties of the problem are greatly magnified.

Formerly a distinction was made between the methods of disinfecting a wooden and an iron vessel. This arose from the fact that almost all wooden vessels have some rotten and spongy wood, especially about the fore-foot and bilge; there are also many more cracks and open joints about a wooden ship than a metal one, which afford lodgment for organic matter and infection. In addition to all this, a wooden hull is always damper than an iron hull, for almost all wooden vessels leak more or less. The micro-organisms are apt to be deeply lodged in the moist dirt and organic matter of the many crevices. A wooden vessel, therefore, as a rule, requires a very thorough mechanical cleansing and a longer exposure to the germicidal agents to insure penetration and disinfection.

While the general method of treating vessels is the same for most of the bacterial infections, special measures are called for with each disease. For example, with cholera particular attention must be paid to the water; for plague the destruction of the rats and other vermin is of prime importance; for yellow fever and malaria efforts must be directed against the mosquito; for smallpox and the exanthematous diseases the usual surface disinfection of the living apartments, the clothing, bedding, and the like, is required.

A vessel is rarely so badly infected that it needs a disinfection throughout. Just what portions of the vessel and its contents require treatment is often a very difficult problem to solve. There is no more reason to fumigate the hold of a vessel because a case of smallpox appeared in the cabin or steerage, than there would be to disinfect the basement and sub-basement of a tenement house because a case had appeared in one of the upper stories of the building. When an infectious disease breaks out on board a vessel, the infection may be confined to one or two compartments or a limited area quite as successfully as may be done in buildings on shore. "In case of doubt, disinfect" is not a bad rule for the quarantine officer to follow in his practical dealings with ships, for, after all, the measures which we take must from the nature of the case be greatly in excess of the absolute requirements.

A great deal may be learned by a very thorough inspection of the vessel. To be sure, we cannot see the germs with our unaided vision, but we can see the dirt and moisture and other conditions which favor their life and virulence.

It is, therefore, the duty of the quarantine officer, or whoever has charge of the disinfection of the vessel, to require a very thorough mechanical cleansing of all its parts which in his judgment require it. This matter is dwelt upon with emphasis in the purification of vessels, because filth is a condition too frequently met with on the sea, and one of great importance to communities and nations. The introduction of an exotic pestilence is a very serious matter to a community, and it is just such infections that are spread from land to land by vessels.

The disinfection of a large vessel cannot effectively be done without all the modern contrivances of a well-equipped quarantine station. A rowboat, a launch, or small sailing craft may be disinfected with a tub of bichlorid solution, but good work cannot be accomplished on larger vessels by the use of makeshifts.

Before the disinfection of a vessel is commenced it should be brought alongside the pier or barge containing the necessary appliances. All the passengers are then to be taken off, and all the crew, only excepting the few who are necessary for the safety of the vessel and those who are to help in the disinfection. The quartermasters, the boatswains, and the carpenter are very useful hands to aid in the process, on account of their practical knowledge of the individual peculiarities in the construction of the vessel and their intelligence in carrying out directions with faithfulness.

When the personnel have left the vessel, all their effects are removed and disinfected in accordance with the methods outlined for objects of that class.

The baggage, bedding, and other objects, no matter what their character, after disinfection should not be returned on board until the vessel itself is finished. This injunction applies, of course, equally well to persons. No one should be allowed on the vessel except those actually engaged in the work, who as far as practicable should be immune, and should wear suitable garments.

All the bedding, bed clothing, hangings, floor runners, and other fabrics must now be removed to the steam chambers for disinfection.

Especial care must be taken to obtain all the used and soiled linen, which is usually kept in special compartments called the "dirty linen lockers," and are under the care of one of the stewards. For some reason the stewards who have this material, which is so apt to be infected, in their care, dislike to disclose its presence to the quarantine officer.

After all the objects needing disinfection by a special process have been removed, attention is then directed to the vessel itself. The various compartments of the vessel may be disinfected by any of the methods described under room disinfection.

A favorite way of disinfecting the forecastle, the steerage compartments, quarters for petty officers and similar apartments, is by flushing them with a bichlorid solution. This may be applied with a force pump, by mops and buckets, or by tricing up a tub of solution sufficiently high to give a good pressure. In applying the disinfecting solution with a hose, begin at one end of the deck ceiling and systematically flood every inch of surface, coming down the walls and finally the floor. Apartments that are very dirty will need a mechanical cleansing either with a lye solution and stiff brush, or with a carbolic or sublimate solution, depending on circumstances.

The cabins, saloons, and similar apartments usually contain metal and bright work, which are ruined by bichlorid or sulphur. They must, therefore, either be given a formaldehyd fumigation or a washing down with a 5 per cent. carbolic acid solution.

In disinfecting large vessels it is well to start forward with the forecastle and work aft systematically, first on the starboard and then the port side, taking care to require every door to be unlocked, and trusting only to a personal inspection concerning its contents and uses. There are certain places, like the lamp room, the paint locker, the sail locker, the chain locker, the carpenter shop, the chart room, and pilot house, the engine and boiler rooms, all the machinery, and the like, that are rarely infected and, as a rule, need no treatment. Special care must usually be directed to the sick bay and any apartment in which a patient was cared for, and all the living apartments, especially the steerage.

The water-closets on board ship should be thoroughly cleansed and flushed with water and disinfected with milk of lime or any of the disinfecting solutions. They may be hosed with the bichlorid solution while that is being applied. In sailing vessels of the older type the forepeak needs similar treatment.

The Hold.—About the best way to disinfect the holds of vessels is by sulphur fumigation or by a solution of corrosive sublimate applied with a hose. It is often desirable to use both methods, in which case the sulphur should always precede the hosing in wooden vessels, because the water may seal many of the cracks and thus prevent the gas penetrating.

In the hold, attention must be given to the bilges. They may be flushed with carbolic or formalin solutions and then pumped out. Care must be taken in using bichlorid solution for fear of injuring the pump.

Before applying sulphur dioxid to the hold of a wooden vessel open all the limbers and air streaks, so that the gas may penetrate between the skin and the hull. If the sulphur is burned in iron pots, set them in a pan of water, which will guard against fire and by evaporation give the requisite amount of moisture necessary for the germicidal action of the gas. Place the pots in an elevated position, either on piles of ballast or on the 'tween decks, because the sulphur fumes first rise, afterward fall, and if the pots are near the bottom, the fire may go out for want of oxygen. In leading sulphur fumes into the hold from a sulphur furnace by means of a system of conduits and pipes, it is considered best to lead the pipes down the hatch well toward the bottom of the hold, so that the apartment may fill up with the fumes from the bottom, displacing the air above. For this reason openings above for the escape of the air must be provided. This is best managed by leaving open one or two of the ventilators, or part of the hatch, and after the gas has begun to escape in some quantity to close up tight.

In disinfecting a ship it is very easy to calculate the amount of sulphur to be burned from her tonnage. A register ton is 100 cubic feet. Count half a pound for each ton, which will make the necessary 5 pounds per 1000 cubic feet.

The gross tonnage of a vessel indicates her actual cubic capacity. The net tonnage gives the capacity of her cargo-carrying space. The difference between the two will give the capacity of the spaces devoted to the engines and machinery, living apartments, and storerooms, etc. In sailing vessels and in freighters the net tonnage may be taken as the cubic capacity of the hold.

In freight vessels 40 cubic feet of merchandise is considered a ton, provided the bulk does not weigh more than 2000 pounds. This ton used as a commercial unit for freight charges must not be confused with the registered tonnage based upon the measurement of the vessel.

The holds of vessels infected with yellow fever should always be given a preliminary fumigation with sulphur before they are inspected, in order to kill the mosquitos and thereby protect the quarantine officer and his employees from infection.

The empty hold of an iron steamer may be disinfected by steam, provided the hold is above the water line. The compartments of such vessels often have steam pipes for use in case of fire. The same system may be utilized for the disinfection of the compartment or for the disinfection of clothing and other fabrics by streaming steam.

The water tanks and casks of vessels are very apt to carry infection. The water itself may be infected with cholera, typhoid, dysentery, or other water-borne infections; or the water may contain mosquito larvæ, which may play serious havoc in case of yellow fever or malaria. It is, therefore, necessary in the first case to disinfect the water by adding formalin (1 per cent.) or carbolic acid (3 per cent.) and let it stand several hours before disposing of it. Sometimes the water may be boiled *in situ* by leading a steam hose into the tank. In the case of mosquito larvæ it will be necessary to use petroleum or one of the other insecticides. If the harbor is on salt water the water containing the larvæ may be spilled with safety into the water, as neither the anopheles nor the stegomyia will develop in salt water.

Cargo.—As a rule the cargo of a vessel infected with a pestilential disease need not be disinfected. There is no reason to consider the cargo of a vessel that has had a case of cholera, or smallpox, or typhus fever, or the like, on board, as having been contaminated, because, as a rule, the cargo hatches are kept well battened down during the voyage and there is little or no communication with the infection. Individual articles of the cargo, such as rags, household goods, second-hand articles, or food products, from infected localities may need treatment. New articles of merchandise or new manufactured goods seldom carry infection.

There is one exception to this, in the case of a vessel infected with plague. In such a ship the rats carry the infection deep down among the cargo and in and about the bilges. It is very important not only to destroy the rats, but also to dispose of their dead bodies without allowing the infection to spread. This can best be done by a process of fractional disinfection, which is done as follows:

After a preliminary sulphuring overnight, some of the cargo is placed upon a lighter, carefully examining every piece, as it is strapped preparatory to hoisting out of the hold, for dead or live rats. Bales of cotton, feathers, and rags, and similar articles must be inspected for nests. The unloading should only be done during daylight. At nightfall the hatches are again battened down and the fumigation is repeated. The process is continued by alternately unloading by day and fumigating by night until the hold is empty. The cargo upon the lighter should be freely exposed to the sun for one or two days before it is taken to the dock. It needs no other disinfection.

This is a rather expensive and tedious process, but there is no other way known by which the cargo may be removed from a plague-ridden vessel without allowing the infection to escape. The dead rats found upon a plague ship should not be handled while the bodies are still warm for fear of the fleas which may carry the infection. In any event it is well to first saturate the bodies of the rats and a considerable surrounding area with a strong disinfecting solution or insecticidal gas, when they may be taken up with tongs or with the hands protected by gloves or towels wrung out in a disinfecting solution.

Ballast.—Vessels bring two kinds of ballast:

1. Water.
2. Solids.

Water ballast is particularly dangerous when it has been obtained from a river, fresh-water lake, or other body where cholera, typhoid fever, or dysentery prevails. It is a rule in quarantine practice to require vessels in fresh-water ballast from cholera-infected districts to return to the open sea, where the ballast tanks are pumped out and refilled with salt water. Some one should be sent along to see that the process is properly carried out.

It is not always expedient to send a vessel to sea, but whether the water ballast is pumped into the river or harbor or at sea, there should first be introduced into each tank, if practicable, a sufficient quantity of formalin or carbolic acid to make a strong germicidal solution, and this should be left several hours before it is pumped out.

Ballast Consisting of Solids.—Vessels bring the greatest variety of substances as ballast. The kind which is most apt to carry infection is called sand by the captain, but an inspection of this "sand" will discover the fact that it consists largely of the street sweepings and rubbish from the port from which the vessel hails. Such ballast should under no circumstances be unloaded on the city front, especially if it comes from an infected district. Ballast which consists of clean, hard rock, or sand from the beach is not apt to carry infection of any kind and usually needs no attention from the quarantine officer.

It is difficult to dispose of ballast, because most vessels, particularly sailing craft, depend upon this weight for their upright position. Almost all harbors have rules forbidding the dumping of ballast and other materials in the harbor; it is, therefore, necessary to have what is known as a ballast wharf to successfully handle this perplexing problem. The ballast is removed from a portion of the hull, which is then disinfected and refilled with a sufficient quantity of new ballast from an unquestionable source. This is repeated until all the old ballast has been removed. In case a vessel arrives with such ballast at a port where there is no ballast wharf, the ballast may be placed upon lighters, which are dumped at sea, or the vessel may be given enough additional ballast to enable her to go to sea in order to jettison her infected ballast. In the latter case care must, of course, be taken to trim the two kinds of ballast so that they will not come in contact.

WAGONS. See Carriages; also Railroad Cars.

WALLS. The walls and ceiling of a room are as a rule infected only superficially, and may be effectively disinfected by one of the gaseous processes. Such surfaces may also be disinfected by washing down with bichlorid or carbolic solutions, preferably hot and applied by means of a hose or any other method that will thoroughly wet the surface. The solution is allowed to remain until it dries and is followed by a mechanical cleaning. When practicable, it is better to scrub or mop the wall with the hot disinfecting solution, by means of brushes, cloths, etc. The spraying of walls and other surfaces with a very fine spray of corrosive sublimate solution or any other material that is not volatile at the ordinary temperatures is a very faulty method, for the entire surface is not wetted and portions thus escape disinfection. In applying a solution with a hose it is always advisable to begin with one corner of the ceiling, and systematically wet every portion of the ceiling, walls, and floor from above downward. This method is particularly applicable to the holds and compartments of vessels, to freight cars, outhouses, cellars, water-closets, wooden buildings, and other rough structures.

A very effective method of disinfecting the walls and other surfaces of a room is to spray them liberally with a strong formalin solution with a Behm's sprinkler (see page 113), or to wet the entire surface with a weaker solution (5 per cent.). The operation must be done quickly and the room immediately tightly closed and kept so at least twelve hours.

Outhouses, water-closets, cellars, and similar rough surfaces, after a preliminary disinfection or cleansing, may with advantage be coated with whitewash made from freshly slaked lime, which in itself is a good disinfectant.

In Germany the method of rubbing the walls with fresh bread has been proposed, but it is tedious, expensive, and not reliable.

WATER.

Water is one of the principal means of spreading the intestinal diseases, such as cholera, typhoid, dysentery, and the like. Small amounts intended for drinking and culinary purposes may be rendered safe by filtration or by boiling. The addition of chemicals is not generally advisable. Water may be filtered through kaolin (Pasteur-Chamberland), or similar filter of fine diatomaceous earth (Berkfeld), so that it is sterile and entirely harmless so far as its power of conveying disease is concerned. Filters, however, should not be depended upon in a household, for the reason that they are untrustworthy, and thereby give a sense of false security. The best filter will only work bacteriologically pure a week or two, when the microbes grow through the pores of the filter. Further, while filters are theoretically perfect, they often have imperfections in construction, such as imperfect joints, or pinholes, or cracks. Such filters deliver a clear, sparkling-looking water, in which, however, lurk the same germs found in the raw water.

For household use the best method of treating an infected or suspected water is first to filter it with any process that will clarify the water and then to boil it. It should be thoroughly boiled for ten or fifteen minutes. Many people object to boiled water because is tastes flat. This is owing to the dissolved air being driven out by the boiling, which may be obviated by shaking or by agitation with an egg beater, or by other mechanical means so that the air may again become dissolved, which gives the water life and makes it palatable.

It is a mistake to boil water first and then filter it. The opposite should always be done. The filtering is too uncertain and should not be depended upon for more than taking out the coarser particles in suspension.

Water that is infected or suspected of being infected with cholera, typhoid fever, or other pathogenic micro-organisms on board a ship, or in casks or cisterns must be disinfected before it is disposed of. This may be done by adding formalin 3 to 5 per cent., allowing it to remain several hours. On board ship the water can sometimes be boiled *in situ* by leading a steam hose right into the tank.

WATER, BATHING.

The water used for bathing the patient is often contaminated, especially by cases of typhoid fever, cholera, the exanthemata, etc. Such water should be disinfected before being allowed to flow away. This may be done cheaply by adding milk of lime in the proportion of 1 : 50; or carbolic acid sufficient to make a 3 per cent. solution and allowing it to stand an hour. Formalin is useful for this purpose and should be added so that the 40 per cent. formalin solution is present in the water in the proportion of 3 to 5 per cent.

Bichlorid of mercury should not be used in metal tubs or where the water flows through lead pipes or soldered joints.

WATER TANKS. See Vessels.

WATER PIPES. The water pipes become infected either from the water that flows through them or from breaks, leaky joints, etc. The entire system of a city may be involved, or the short lead of a local supply. After the source of the trouble has been corrected, the pipes must be disinfected before the water coming from them can be considered safe. For this purpose it is desirable to use something that is not poisonous. Formalin or milk of lime is best suited, though carbolic acid has been used. Bichlorid of mercury is too poisonous to be considered in this connection and, besides, it must not be used where there is lead piping.

In Nietleben, Koch disinfected the entire system of the town by introducing a 3 per cent. solution of carbolic acid into the pumps, and allowing it to flow into all portions of the pipes, where it remained twenty-four hours. The carbolic acid was then washed out with water. This has the disadvantage that the water will taste of the carbolic acid for a long time.

Milk of lime is effective, but has the disadvantage of tending to obstruct the pipes. Formalin is expensive, but is preferable for this purpose on account of its high efficiency, its quickness, and its non-poisonous character. Formalin is particularly applicable to the disinfection of the water pipes of wells, cisterns, and small supplies of this character.

WELLS AND CISTERNS.

The only trustworthy way of rendering the water from an infected well or cistern safe is to boil the water before using it, and to correct the evil at its source. It is not necessary to emphasize the fact that, where possible, all suspicious water-supplies should be avoided; but circumstances may arise by which a well or cistern, the only readily available source of water-supply for an isolated camp, quarantine station, farm-house or ship, may be infected and seriously inconvenience the users of the water, unless some safe remedy is at hand. It is practicable to disinfect wells and cisterns provided the contamination is not continuous or repeated. The method to be used varies, depending upon whether the scarcity of water necessitates the use of the infected water itself or whether a new supply may be at hand.

If the infected water must be used it should be boiled. No other method of purifying it, such as filtering or adding potassium permanganate, etc., should be trusted. If the well or cistern may be disinfected with its contents and the water then discharged, one of the following procedures will be safe:

The best disinfectant for this purpose is formalin, on account of its high efficiency and its non-poisonous nature. Enough of the strong (40 per cent.) formalin should be added so that it will be present in the proportion of at least 1 per cent. After standing several hours the well or cistern should be thoroughly washed with the solution, not overlooking the walls of the well, which must be given a very thorough mechanical scrubbing with a stiff broom and plenty of the disinfecting solution. All parts of the pump, if there is one, and the piping must be purified with the solution.

The disinfection of wells may also be accomplished by the use of freshly burned lime. About half a barrel of lime is thrown into the well, stirred up with the water, and the walls are scrubbed down with the resulting milk of lime. The well is then pumped out, cleaned, allowed to refill, and a second supply of lime added; after which the well is allowed to stand for twenty-four hours. After a thorough stirring the solution is then pumped out and the well is allowed to refill and is re-emptied until the water is practically free from lime.

Wells and cisterns may also be disinfected with carbolic acid, or any of the cresols, or potassium permanganate, but no chemical is as quick and safe for this purpose as formalin.

WOOL.

The raw wool may be steamed, boiled, or immersed in one of the disinfecting solutions. The objection to using boiling water or steam upon woolen fabrics is due to their tendency to shrink. The better grades of woolen cloth are "sponged"—that is, steamed—before being made into garments, and such articles may be disinfected by steam, provided that care is taken to prevent them being pressed or pulled out of shape in the process, and provided that care is exercised to place them in the steam chamber so that they will not be in contact with any of the metal parts, and also provided that as soon as the process is over the articles are stretched and shaken in the air while still steaming hot.

Woolen articles that are injured by steam or hot water may be disinfected without injury by formalin or formaldehyd gas, according to the methods already given for the application of these substances. In the disinfection of woolen goods with formaldehyd gas it is important to use an excess of the gas and a long exposure,—preferably twenty-four hours,—for the reason that the organic matter of the woolen fiber absorbs large volumes of formaldehyd, which not only consumes appreciable quantities, but hinders penetration. The combination of formaldehyd with dry heat, as described on page 110, is particularly suitable for the disinfection of woolens, without injuring them in any way.

CHAPTER VI.

DISINFECTION FOR THE COMMUNICABLE DISEASES.

TYPHOID FEVER.

Typhoid, or enteric fever, is a widespread communicable disease, frequently occurring in severe epidemics.

The symptoms of the disease are very inconstant. A typical case is marked by a continued fever lasting about four weeks, a rose-colored eruption, diarrhea, abdominal tenderness, tympanites, and enlargement of the spleen.

The period of incubation is variously stated from eight to fourteen days, sometimes twenty-three.

The cause of typhoid fever is a short, actively motile rod, called the *Bacillus typhosis*, sometimes the Eberth bacillus, in honor of its discoverer, who described the organism in 1880.

The bacillus of typhoid fever does not have spores.

The organism is taken into the mouth, passes into the intestinal canal, where under favorable conditions it grows and multiplies, invading the system, giving rise to the lesions and the symptoms of the disease. A catarrhal condition exists throughout the small and large intestines, and the lymph follicles become swollen, hyperplastic, and may ulcerate. The bacillus is readily found in the inflamed lymphoid tissue, also in the rose-colored eruption, the enlarged spleen, and mesenteric glands. The bacillus frequently invades the blood, and may be found widely disseminated throughout the organs and tissues of the body.

The typhoid bacillus produces a soluble poison in the course of its growth, called typho-toxin. It is this poison which is largely responsible for the fever, the inflammation of the lymphoid elements of the body, the effect upon the heart and nerves, and the more serious features of the disease.

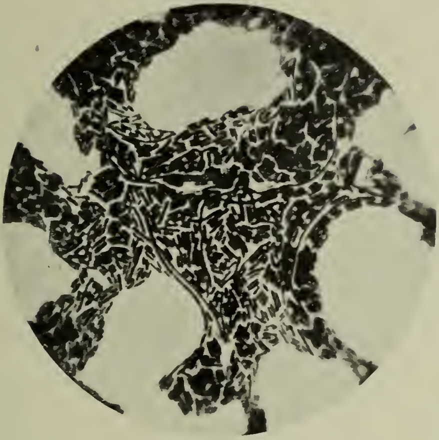
The bacillus of typhoid fever is eliminated from the body in the stools, the urine, and sometimes in the sputum, so that practically all the discharges from the body may contain the infective agent and must be disinfected in order to prevent the spread of the disease.

The discharges from the patient contaminate the water, the milk, and the food-supply. It is largely in this way that the disease is spread from the sick to the sound. Typhoid fever may be communicated through the medium of articles of diet other than the water and the milk. For instance, green vegetables, such as salads, radishes, celery, and the like, that are eaten without previous cooking, may be contaminated with infected water or soil that has been fertilized with the human manure. Raw oysters have also been known to set up several small epidemics of the disease.

There is little evidence to show that typhoid fever is airborne, or that the infection is, as a rule, taken into the system in any other way than by the mouth. This is a very important fact in applying our disinfecting agents for the suppression of the infection. It is true that pulmonary forms of the disease without intestinal lesions have been reported, but such instances seem to be exceptional.

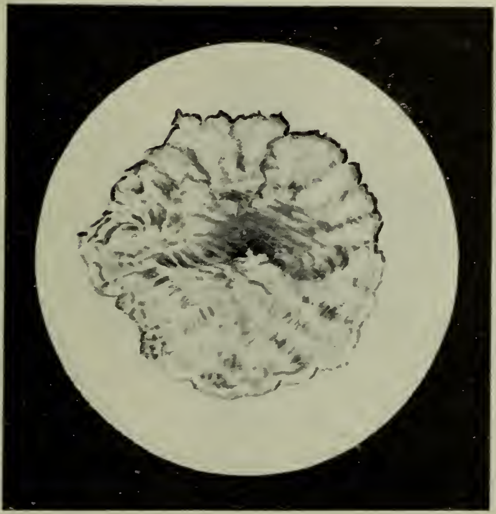
Flies are responsible for much of the spread of typhoid fever. They breed in and feed upon the dejecta and the infected discharges, thereby conveying the infection di-

FIG. 54.



TYPHOID BACILLI, PURE CULTURE.

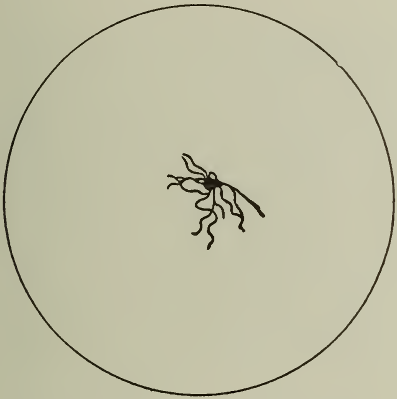
FIG. 55.



TYPHOID COLONY ON GELATIN.

rectly to the food-supply. It is easy to understand how flies, and other insects with similar habits, carry the typhoid bacilli smeared upon their feet and bodies, as well as in their intestinal contents, thereby contaminating the meat, the butter, and other foods, especially the milk, in which this organism grows so well. A can of milk contaminated with a few typhoid bacilli may, in a few hours, at ordinary temperature, be teeming with the infection, without producing any apparent change in the milk. Flies, by alighting upon our lips or other portions of our body, may be the means of introducing the infection more directly into our mouths. The importance which flies play in spreading the infection of typhoid fever is not realized. This factor must always be taken into account in applying our disinfectants and other means to limit the spread of the infection.

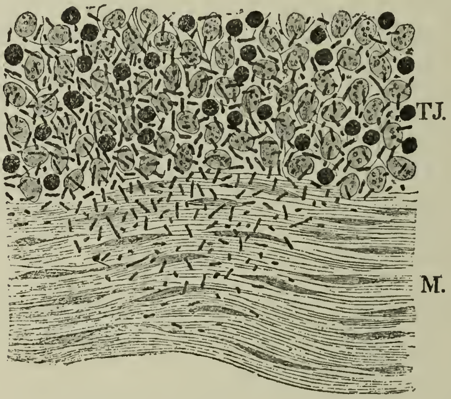
FIG. 56.



TYPHOID BACILLUS WITH FLAGELLA.

The typhoid bacillus is a hardy organism. It is found in the water, the soil, the air, the dust, sewage and in the milk, as well as upon soiled clothing, etc., contaminated directly or indirectly by the discharges of the sick. It finds abundant conditions in nature for its growth and development and enjoys the power of accommodating itself more readily to environment than the majority of the pathogenic bacteria. For instance, the addition of from 0.1 to 0.2 per cent. of carbolic acid to the culture media does not retard its growth and development. It may retain its vitality for three months in distilled water, which indicates what a minute amount of organic matter is necessary for the life of the typhoid bacillus.

FIG. 57.



TYPHOID BACILLI INVADING THE SUBMUCOUS (TJ.) AND THE MUSCULAR (M.) COATS OF THE INTESTINES.—(*Baumgarten.*)

A moist temperature of 60° C. will kill the bacillus of typhoid fever in ten minutes, and boiling water or steam at a temperature of 100° C. will destroy the vitality of the bacillus at once. It usually dies quickly when dried, although it has been kept alive several months on fabrics.

It is apparently not affected by freezing. It soon dies when exposed to the bright, direct rays of the sun.

Formaldehyd and sulphur dioxid kill this bacillus in the strengths and times stated for the employment of these gases.

All the ordinary germicidal solutions in the strengths given for the destruction of non-spore-bearing bacteria are efficient disinfectants for the typhoid bacillus; for example, bichlorid of mercury 1 : 1000, carbolic acid 3 to 5 per cent., formalin 3 to 5 per cent., tricresol 1 per cent., etc.

The disinfection for typhoid fever begins with the destruction of the infection in the discharges as they leave the body, before they have a chance to contaminate the surroundings, the water or food-supply.

The evacuations from the bowels should be received in a vessel containing a 5 per cent. solution of carbolic acid, 2 per cent. tricresol, or 5 per cent. formalin. More of the solution must be added afterward so that it is present in equal volume and thoroughly incorporated throughout the mass. The mixture should stand one hour before it is disposed of. Bichlorid of mercury is not suitable for the destruction of the infection in the dejecta on account of its property of coagulating and combining with the albuminous matter, which prevents its penetration. Lime and its various compounds are cheap and efficient disinfectants for this purpose and the methods for their use are given on page 202.

The urine frequently contains the infective agent of the disease and is usually disinfected with the evacuations from the bowel. If passed separately it may be disinfected by adding sufficient bichlorid of mercury to make a 1 : 1000 solution, or carbolic acid 3 to 5 per cent., tricresol 1 per cent., or formalin 3 to 5 per cent., and allowed to stand one hour before it is discarded.

The sputum will also need treatment as it frequently contains the typhoid bacillus. The proper methods of disinfecting the sputum have been given upon page 226, and need not be repeated here.

All materials that have become contaminated with the discharges from a case of typhoid fever must be disinfected by appropriate methods. This applies especially to the towels, bedding, and other fabrics used about the case. As boiling water or steam destroys the vitality of the typhoid bacillus instantly, either of these methods is particularly applicable to the disinfection of objects of this class. If the bedding is not soiled it may be immediately boiled, otherwise it must be treated so as to take out the albuminous materials in order to prevent indelible staining, resulting from the coagulation and fixing of these materials in the fabric.

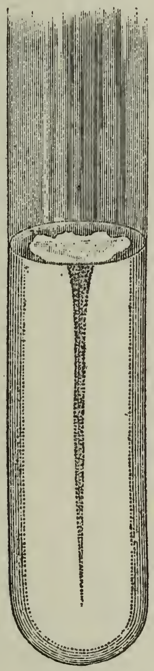
The bedding and fabrics contaminated with the infection of typhoid fever may also be disinfected by immersion in one of the germicidal solutions mentioned above.

The bedding should be changed frequently and everything about the sick-room kept clean and fresh. The room should be well ventilated and the floor and surfaces kept clean and free from infection by frequent mopping with a 1 : 1000 bichlorid solution. The patient himself will need scrupulous attention and careful nursing in order to keep his skin clean. The mouth and lips need frequent washing with listerine, boracic acid, or other mild antiseptic solutions. The buttocks must be cleansed and washed with a 1 : 1000 bichlorid solution, and the rags used for this purpose had best be burned.

The food may be disinfected by thorough cooking and the milk by boiling or Pasteurization, which consists in heating the milk to a temperature of 70° C. for half an hour and then chilling it suddenly. After the food and milk have been disinfected it is important to guard against their recontamination, by contact with infected water or by flies.

The spoons, cups, and other tableware should be scalded before being used again, and the remnants of food remaining from the patient's meal should be burned or boiled before being thrown out.

FIG. 58.



A STICK CULTURE OF THE TYPHOID BACILLUS IN GELATIN.

The hands of the nurse and others who come in contact with the patient or his discharges must be very carefully disinfected by immersing them in one of the germicidal solutions (see page 209). This procedure is important from a general standpoint of preventing the spread of the disease, but is doubly important on the farm or dairy, where the same hands that nurse the sick or handle the dejecta afterward milk the cows.

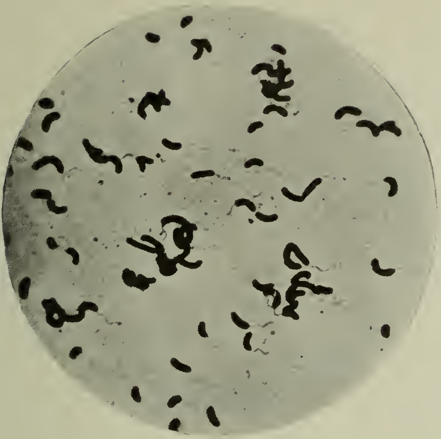
The sick-room should be carefully screened to prevent the annoyance as well as the danger of flies. Any insects found in the room should be caught and burned.

In cases where the above precautions have been intelligently carried out there is no reason to fear the spread of the infection, and it is not necessary to practise a general disinfection with one of the gases. In fact, both formaldehyd gas and sulphur dioxid are of little practical use in combating an infection that is taken into the body through the alimentary canal and not the respiratory system. In other words, it is more important to boil the drinking water, and to thoroughly cook the food, and to Pasteurize the milk, and to protect against the infection carried by flies, than to attempt to destroy with one of the gases the typhoid bacilli that may contaminate the surfaces of exposed objects.

CHOLERA.

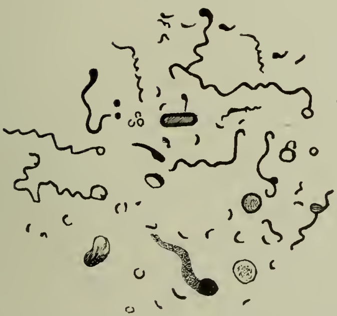
Cholera is a communicable disease native to India, where it is always present, sometimes existing in widespread and very fatal epidemics. From time to time it is transported along the lines of travel and commerce to all parts of the world. Many severe epidemics have been caused in seaport towns by the introduction of a few cases on a vessel. Cholera is often called Asiatic cholera on account of its home in India, and to distinguish it from cholera nostras, cholera morbus, and other forms of non-communicable affections with choleraic symptoms.

Fig. 59.



Spirillum of Cholera.

Fig. 60.



Involution Forms of the Spirillum of Cholera.—(*Van Ermengem.*)

A typical case of cholera is characterized by violent purging, cramps, rice-water discharges, and rapid collapse.

The period of incubation varies from a few hours to five days.

The disease is due to the "comma bacillus" discovered by Koch in 1883–1884. This micro-organism is curved or spiral-shaped and is therefore now called the *Spirillum choleræ asiaticæ*. It is actively motile, and grows very well on alkaline media containing the slightest trace of albuminous matter, at ordinary temperatures as well as at the temperature of the body.

The spirillum of cholera does not have spores.

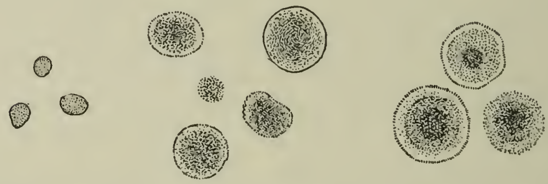
In the body the infection is confined to the alimentary tract. The cholera spirillum is practically always introduced into the system in the drinking water or with the food. It may also be introduced into the mouth by means of the hands or other objects that have become soiled with the infection. Of all the diseases of man that occur in epidemic form cholera is the type of the water-borne infections. There can no longer be any doubt but that the great outbreaks of this disease in large communities are always due to the contamination of the drinking water. The spirillum of cholera grows well in milk, and will keep alive and virulent a long time in moist albuminous food-stuffs, so that articles of food may spread the infection as well as the water. Vegetables and fruits are apt to become infected with the polluted water or from other sources, and if eaten raw may cause the disease.

The flies play a similar rôle in spreading the infection of cholera that they do in typhoid fever.

After the cholera spirillum passes the acid juices of the stomach, it grows and multiplies in such enormous numbers in the intestines that every drop of the mucous discharges from the intestines may contain myriads of the organisms. During the course of its growth and multiplication it produces a poison or toxin which gives rise to the diarrhea, vomiting, cramps, and prostration which characterize the disease. The spirillum of cholera remains confined to the intestinal canal. It does not invade the blood, and is therefore only eliminated from the body in the matters passed from the bowels, and sometimes in the vomit.

The cholera spirillum is somewhat less resistant to external influences than the typhoid bacillus, and the same agents used for the destruction of the typhoid bacillus may be used for the destruction of the infection of cholera.

FIG. 61.



COLONIES OF THE SPIRILLUM OF CHOLERA AFTER TWENTY-FOUR, FORTY-EIGHT AND SEVENTY-TWO HOURS' GROWTH ON GELATIN PLATES.—(*Curtis.*)

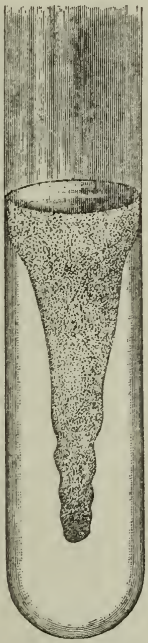
A moist heat of 65° C. will kill the spirillum of cholera in five minutes. Boiling water or steam at 100° C. kills the infection almost instantly. Most authorities agree that it dies quickly when dried, usually in from three to four hours. In a moist condition it retains its vitality for months, especially in the presence of organic matter, but it soon loses its virulence. The sunlight is also quickly fatal.

The organism may live a long time in water, as may well be imagined from the fact that the disease is water-borne. In fact, it has been shown that if planted in sterilized water this organism grows with great rapidity and can be found alive after months have passed.

Formaldehyd and sulphur dioxid kill the spirillum in the strengths and times stated for the employment of these gases.

All the ordinary germicidal solutions used in the strengths given for the destruction of non-spore-bearing bacteria are efficient disinfectants for the cholera spirillum. For example, bichlorid of mercury 1 : 1000, carbolic acid 3 to 5 per cent., tricresol 1 per cent., formalin 3 to 5 per cent., etc.

FIG. 62.



SPIRILLUM OF CHOLERA GROWING IN GELATIN, SHOWING LIQUEFACTION.

The disinfection of cholera begins at the bedside. In general the measures and methods described to prevent the dissemination of the infection of typhoid fever are applicable for cholera, and need not be repeated in detail.

Most important is the destruction of the infection in the stools and in the vomited matter. For this purpose use formalin 5 per cent., carbolic acid 5 per cent., tricresol 2 per cent., or lime, and thoroughly incorporate the disinfectant throughout the mass and allow it to remain covered one hour. The above substances are considered the most trustworthy for the disinfection of these materials in small amounts, but in their absence other germicides mentioned in the article on excreta (page 202) may be used. Bichlorid of mercury is not applicable for this purpose on account of its lack of penetration in the presence of albuminous matter.

All the bedding, body linen, towels, and other fabrics that have in any way come in contact with the patient, or his discharges should be immediately boiled, steamed, or immersed in one of the disinfecting solutions. The hands of the nurse and the body of the patient must also be kept clean and free from infection by frequent use of one of the disinfectants applicable to this particular purpose.

The excreta and all objects that have become contaminated must be disinfected at once, or, if this is not possible, they must be carefully protected from the flies and other insects.

When cholera prevails or is present in epidemic form, it is essential to boil all the drinking water and thoroughly cook all the food. More than this, it is important not to eat or drink out of cups or plates that have been washed with the infected water. All the tableware must be scalded, the milk boiled or Pasteurized, and no green vegetables, such as salad, radishes, celery, and the like, partaken of, unless first treated with tartaric acid and washed as described on page 207.

There is no need to practise disinfection with one of the gases after a case of cholera where the above precautions have been carried out. If through ignorance or neglect the infection has contaminated the room and its contents, a general disinfection may be done with formaldehyd gas or sulphur dioxid according to the methods described for applying these agents for non-spore-bearing infections.

So well do we know the habitat of the cholera spirillum in nature, as well as its channels of introduction into and discharge from the body, that we can apply our germicidal agents with great accuracy and with every assurance of destroying the infection and limiting the spread of the disease; in fact, our methods have reached such a satisfactory state that it is possible to live in the midst of a raging cholera epidemic without contracting the disease.

DYSENTERY.

Dysentery is a communicable disease, occurring in widespread epidemics with great fatality, especially in the tropics and warm climates. The disease is characterized by an inflammation of the lower bowel, accompanied with frequent and painful stools, often bloody. The symptoms of dysentery may result from one of many different irritating poisons, but the communicable dysentery with which this article deals is a specific disease, due to a definite living entity, the *Bacillus dysenteriæ*, described by Shiga in 1899. It is a short, actively motile rod, closely resembling the bacillus of typhoid fever.

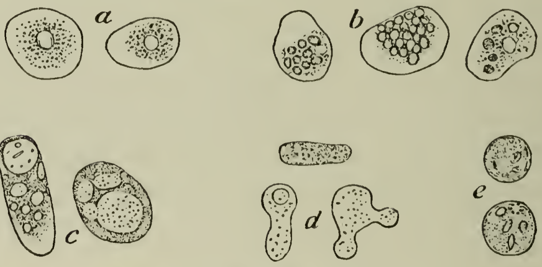
The bacillus of dysentery does not have spores.

It is believed that dysentery is transmitted in very much the same way that typhoid fever is. The cause of the disease is taken into the intestinal tract usually with the drinking water. The milk and food may also convey the infection. As the poison is excreted from the body in the evacuations from the bowels it is reasonable to suppose that the flies and other insects may play a part in disseminating the infection.

The vitality of the bacillus of dysentery is precisely similar to that of typhoid fever, and the principles of disinfection are the same as for that disease, so that it is not necessary to repeat them here.

Another form of communicable dysentery prevalent in tropical and warm climates is believed to be due to a protozoon—the *Amœba dysenteriæ.* This form of the disease is usually chronic, and, so far as known, the same methods of prevention and disinfection are applicable to it as to the above.

FIG. 63.



AMŒBA DYSENTERIÆ.—(*After Roos.*)

a. Ameba without any foreign contents. *b.* Ameba containing blood-corpuscles. *c.* Ameba with large vacuoles. *d.* Young forms. *e.* Encysted forms.

DIPHTHERIA.

Diphtheria is a communicable disease, sometimes occurring in severe epidemics among the children.

Diphtheria is characterized by an inflammation of the mucous membranes, especially of the throat. The character of this inflammation varies very much in degree. It may resemble the simple catarrhal inflammation resulting from "catching cold," or when more severe may cause a fibrinous deposit or false membrane, by which the disease has long been recognized clinically. Every degree of severity is met with, from the mildest type to the malignant variety that results fatally in few hours.

Diphtheria is not confined to the throat, but may attack any of the mucous membranes of the body, including the conjunctiva. The disease may also complicate wounds, and open sores may be the seat of a typical attack of diphtheria, accompanied with a false membrane and all the constitutional manifestations of the disease.

The period of incubation is "from two to seven days, oftenest two."

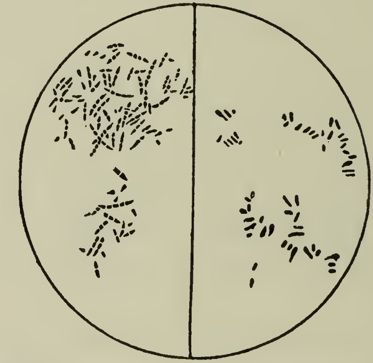
The cause of diphtheria is a bacillus bearing the same name—*Bacillus diphtheriæ*, first seen by Klebs under the microscope in 1883 and isolated in pure culture the next year by Loeffler, who proved this organism to be the cause of the disease. It is therefore often spoken of as the Klebs-Loeffler bacillus.

The bacillus of diphtheria is a non-motile rod of variable length and very irregular in shape. It is often swollen on one end, presenting a club-shaped appearance, or it may be pointed or wedge-shaped. It stains in an irregular manner with the basic anilin dyes that is quite characteristic. The bacillus of diphtheria grows well upon blood-serum and artificial culture media, at the temperature of the body.

It does not have spores.

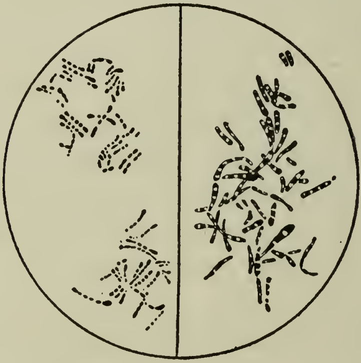
The infection may enter the body in a great variety of ways. It may pass directly from mouth to mouth, or indirectly from objects that have become contaminated with the germs of the disease. The bacilli may be taken into the system with the food, especially milk. The infection may also be taken into the body through the respiratory system, although this is rare. The diphtheria bacillus is not found in the expired breath and the disease is not airborne in the sense that smallpox or typhus fever is. The air may become infected from dried sputum, or from minute

Fig. 64.



Bacillus diphtheriæ. Long Beaded Variety with Pointed Ends and the Short Forms.

Fig. 65.



Bacillus diphtheriæ. Two Specimens of the Medium and Long Varieties with Clubbed Extremities.—(*Curtis.*)

particles that are sprayed from the mouth in the acts of coughing, speaking, gagging, and other acts of expiration accompanied with explosive movements. The infection may also be inoculated into wounds of the skin. When the diphtheria bacillus enters the mouth or lodges upon the mucous membranes, it grows and multiplies, setting up the local inflammation which characterizes the disease. The organism usually remains localized at the seat of the lesion, and rarely invades the deeper tissues or the blood.

During the course of its growth and multiplication the diphtheria bacillus produces a chemical poison—the diphtheria toxin. It is really this toxin, and not the bacillus itself, that causes the local inflammation and the fibrinous exudate with the death of the cells resulting in the production of the false membrane. This toxin is a soluble poison and is readily absorbed into the system, giving rise to the fever, prostration, and the nervous symptoms that frequently are associated with diphtheria.

The bacillus of diphtheria is eliminated from the body with the secretions from the mucous membranes, or with the pus and exudates from wounds, depending upon the seat of the local lesion. The membranes of the throat and larynx being the usual seat of the disease, the infection is most commonly thrown off from the body in the expectoration. Therefore, the sputum and all objects which come in contact with the secretions of the mouth must be carefully disinfected in order to prevent the spread of the infection. The evacuations from the bowels and the urine do not need disinfection in this disease.

It has been found that many persons in good health have live and virulent diphtheria bacilli in the secretion from their mouths; that is, this organism may grow upon the mucous membranes of the throat and be contained in the expectoration without causing the least inconvenience. Such persons are a constant menace to others who are more susceptible to the disease.

The infection may be spread from mouth to mouth by kissing, or, indirectly, by any object that becomes contaminated with the infected secretions. Handkerchiefs, towels, and other fabrics are especially apt to become infected and unless disinfected become sources of danger. Knives, forks, spoons, and other tableware that come in contact with the mouth may carry the infection to other persons who use such articles without previous scalding or disinfection. Play toys are often responsible for the spread of the disease, on account of the habit children have of mouthing such articles.

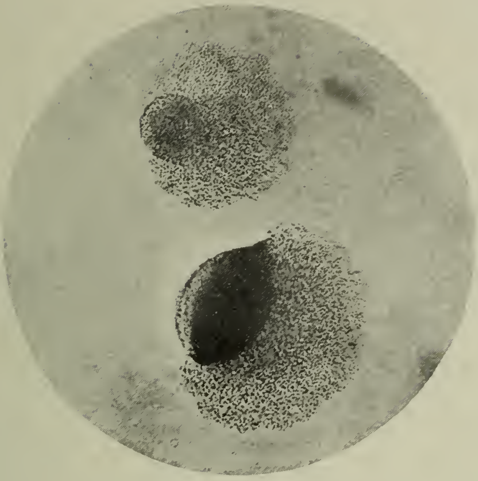
The bacillus of diphtheria grows well in milk, and epidemics of the disease have been traced to this source. The milk is usually infected at the dairy, but may be rendered safe by boiling or Pasteurization. (See page 214.)

The bacillus of diphtheria is readily killed by heat or chemicals. It is destroyed by a moist temperature of 58° C. in a few minutes. Boiling water or steam at 100° C. will destroy the vitality of this infection instantly. It is to be noted that while the bacillus usually dies quickly when dried, under certain circumstances it may retain its vitality a very long time, especially if dried in albuminous matter, such as little bits of the false membrane. This accounts for the long time the infection may persist upon objects that have been contaminated with the secretions from the mouth.

The direct sunlight will kill cultures in from thirty to forty minutes.

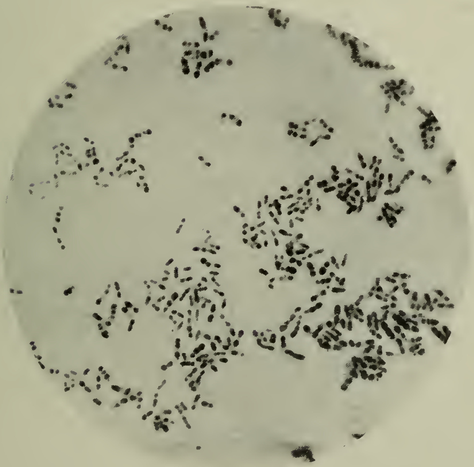
Any of the ordinary germicidal solutions, employed in the strengths stated for use against non-spore-bearing bacteria, are efficient for the bacillus of diphtheria; for example,

Fig. 66.



Diphtheria Colonies on Agar.

Fig. 67.



Diphtheria Bacilli in Pure Culture from Blood-serum.—(*Fränkel and Pfeiffer.*)

bichlorid of mercury 1 : 1000, carbolic acid 3 to 5 per cent., tricresol 1 per cent., formalin 3 to 5 per cent.

Formaldehyd gas kills the bacillus of diphtheria at once when exposed directly to the gas in the strength given in Chapter II. However, an exposure of twenty-four hours is advisable in order to insure diffusion and penetration, for in actual practice the bacilli are not always exposed directly to the action of the gas, as they frequently are in laboratory experiments, but are often encased in the mucoid and albuminous matter of the secretions.

Sulphur dioxid is also an efficient disinfectant for the diphtheria bacillus, but is limited in its practical application on account of its destructiveness.

The disinfection for diphtheria should be done largely at the bedside. The method of treating the sputum has been given in another portion of the volume. Towels, bedding, underclothing, and other fabrics that have come in contact with the patient should be boiled, steamed, or immersed in one of the chemical solutions. The hands of the nurse will need frequent washing and disinfection (see page 209). All objects that have come in contact with the secretions of the patient or that have been exposed to the possibility of infection must be treated by methods appropriate for each article.

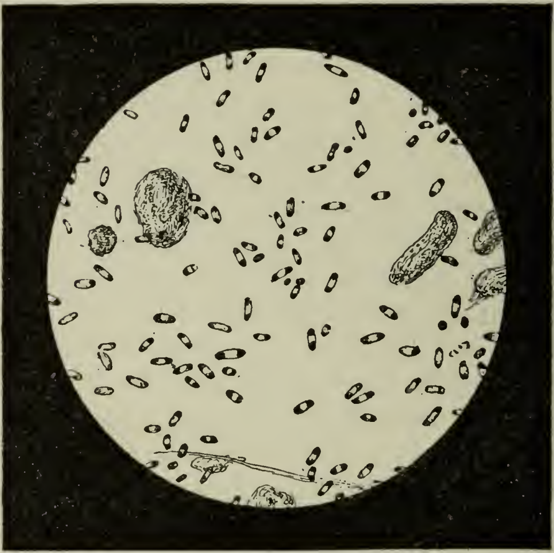
Remnants of food from the patient's meal should be burned or boiled before being discarded. All articles of tableware, particularly those which come in contact with the secretions from the patient's mouth, should be scalded before being used again. The thermometer used to take the temperature must be disinfected.

After the case has recovered, the room should be given a general disinfection with formaldehyd or one of the gases recommended in Chapter II, in order to destroy any infection that may have become diffused in the room.

PLAGUE.

Plague, also called bubonic plague, la peste, black death, and other names, is a communicable disease occurring in widespread and very fatal epidemics in man and some of the lower animals. Of all the epidemic diseases, plague has caused more deaths in a shorter time than any pestilence known to man. In the thirteenth century about one-quarter of all the people living in Europe died of this affection in a few years.

FIG. 68.



PLAGUE BACILLI IN THE SCRAPINGS FROM A BUBO.

Plague manifests itself clinically in a great variety of forms. First cases have been mistaken for typhoid fever, pneumonia, diphtheria, malaria, influenza, and many other diseases. This is due largely to the fact that the plague bacillus enters the body through different channels and sets up an inflammation both at the point of entrance and in the neighboring and distant glands and organs. Very often the organism invades the blood, causing a very severe form of blood-poisoning, which is frequently fatal, sometimes causing death in a few hours.

The period of incubation is usually three to five days, rarely over seven.

The cause of plague is a short, non-motile rod called *Bacillus pestis*. It has a tendency to show bipolar staining when colored with anilin dyes. It grows well upon artificial culture media at the room temperature, and in the incubator kept at the body heat, 37° C. It was discovered by Yersin in the summer of 1894 in the epidemic which was then raging in Hongkong, and has since been confirmed by many scientists in all parts of the world.

The bacillus of plague, in the course of its growth, produces a soluble poison known as the plague toxin, which is absorbed by the system, causing the fever, prostration, and nervous depression which characterize all forms of the disease.

When the plague bacillus enters the body through a wound in the skin, it causes a local inflammation which quickly spreads through the lymphatic channels to the neighboring lymph glands. These become swollen and painful and are known as buboes—hence the name bubonic plague. When the infection is taken into the respiratory tract, the inflammation set up in the lungs resembles very closely that of croupous or lobar pneumonia. When the bacillus is taken with the food or drink into the alimentary canal, it may cause a sore throat, or a tonsillitis, or may give rise to an inflammation of the intestines.

The bacillus of plague may be eliminated from the body in any of the discharges. In the pneumonic form of the disease, the infective principle is contained in the expectorated matter, which is highly virulent. We know that this form of the disease is communicated from the sick to the well more readily than any other variety. The bubonic and septicemic varieties of plague are less readily communicated because the bacillus is imprisoned in the glands and tissues of the body. If the buboes suppurate, the organism is eliminated with the discharge of pus. The organism is also eliminated from the system in the fluid contents of the blisters and with the discharges from abscesses and carbuncles which are frequently associated with the disease. In the intestinal form, the bacillus of plague is thrown off from the body in the alvine discharges. It will, therefore, be seen that practically all the discharges from the body must be disinfected in order to prevent the spread of the disease.

It is important to remember that many animals besides man are liable to this infection. Rats are subject to the disease and sometimes die in great numbers during an epidemic, and undoubtedly spread the infection from place to place. Mice, cats, dogs, cattle, and other domestic animals are also subject to the disease. It is believed that the fleas convey the infection from rats to man. Flies which have fed upon plague-infected material die, and the infection may be spread through their agency. These facts have a distinct bearing upon our methods of disinfection, as well as the other means employed in combating this disease.

Nuttall has shown that house flies which were fed on the organs of plague-infected animals contained virulent bacilli forty-eight hours and more after feeding. He found virulent bacilli in the dejections of these flies two days afterward.

Hankin, in India, has shown that ants, which can devour a dead rat with great rapidity, carry virulent bacilli about in their bodies for some time after feeding upon the body of a plague-infected rat.

These ants and flies may deposit virulent bacilli of plague through their excretions, in food, in drinkables, especially the milk, on the floors, tables, etc., and on the body and clothing of persons. In other words, they distribute the plague germ widely within the limits they travel (Curry).

These insects probably do not inoculate the plague germs into the system when they bite. It is more probable that the irritation caused by the bites induces the individual to scratch or rub the infection into the skin.

The plague bacillus cannot be considered a frail organism, as was at first supposed.* So far as its vitality is concerned, it resembles the bacillus of diphtheria or the micrococcus of pneumonia. In the presence of moist and albuminous matter it may keep alive and virulent a very long time. We know that it may live for months and even years in a test-tube upon the artificial culture media used in the laboratory.

The plague bacillus dies quickly when dry; moisture favors its life. It is more apt to remain alive when dried upon fomites, such as bedding, clothing, food, and other objects, if the temperature is under 19° C.; that is to say, the colder the climate, the greater the danger of carrying the infection upon inanimate objects, and more extensive disinfection is required in combating the disease than in a tropical region.

Sunlight kills the organism in a few hours, provided the sun shines directly upon it and the temperature in the sun is above 30° C. The effect of sunlight is not very penetrating.

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* "Viability of the Bacillus Pestis," Laboratory Bulletin No. 4, M. J. Rosenau, Marine Hospital Service.

The bacillus of plague grows well in milk and may live a long time in cheese, butter, and other similar moist albuminous food products, which may therefore require disinfection in order to prevent the spread of the disease. It usually dies quickly when dried upon the surface of fruits and preserved foods.

The bacillus of plague may live a long time in water, although plague is certainly not a water-borne infection in the sense that cholera and typhoid fever are. The plague bacillus is destroyed in a few minutes by an exposure to moist heat at 60° C. Boiling water or steam at a temperature of 100° C. kills this organism at once. The usual germicidal solutions are all efficient against plague in the strengths in which they are ordinarily used for the destruction of non-spore-bearing infections; for example, bichlorid of mercury 1 : 1000, carbolic acid 3 to 5 per cent., tricresol 1 per cent., formalin 3 to 5 per cent.

The plague bacillus is destroyed by sulphur fumigation and by formaldehyd gas in the strengths in which these disinfectants are used (see Chapter II). While the bacillus is killed in a very few minutes by direct exposure to these gases, an exposure of not less than six, and preferably twenty-four, hours is desirable to insure diffusion and penetration, depending upon the method used to generate the gas.

Formaldehyd gas has little effect upon the higher forms of animal life, and as plague is a disease which is very largely spread through the agency of rats, fleas, flies, and other animals, it is essential to use a disinfectant that will destroy vermin of this character as well as the plague bacillus itself. Sulphur dioxid is very fatal to all forms of life, and it is, therefore, a much more reliable disinfecting agent to prevent the spread of this disease than formaldehyd gas. It is especially useful in warehouses, granaries, ships, and other rough structures infested with vermin.

Chlorin gas and hydrocyanic acid are also useful disinfecting agents in combating the infection of plague, particularly on account of their poisonous nature. Very careful precautions must be taken, in the employment of these gases, to prevent accidents. (See Chapter II.)

The disinfection at the bedside of a case of plague must be rigorously carried out in order to prevent the spread of the disease. The sputum, the dejecta, and the urine may contain the infective principle and must be disinfected. The bacillus is also found in the blood, in the serum of the blisters, and in the pus and discharges from the buboes, ulcers, and other sores which may be present. The methods of disinfecting these materials have been described in detail in another chapter and need not be repeated here.

The same precautions must be taken with the patient's body, the hands of the nurse, and all objects which come in contact with possible infection that have been described under typhoid fever. The bedding, body linen, towels, and other objects which have come in contact with the patient or his discharges should be disinfected by boiling, steaming, or immersion in one of the germicidal solutions, or treated according to the methods appropriate for each particular object.

The sick-room must be kept thoroughly ventilated, sweet and clean, and carefully screened. In addition to scrupulous cleanliness at the bedside, all exposed surfaces of the room should be mopped with a solution of bichlorid of mercury 1 : 1000 at frequent intervals. The greatest care must be taken to prevent the spread of the infection from the pneumonic type of the disease, for the live and virulent bacilli are thrown out with the sputum that is sent out into the air in a fine spray during coughing, hawking, sneezing, and other explosive expiratory acts. The infection thus disseminated into the air is breathed into the respiratory tract of those who come in contact with the patient or his surroundings, and the disease is frequently spread in this way.

TUBERCULOSIS.

Tuberculosis is a communicable disease prevalent in all parts of the world. So many victims does it claim every year in civilized communities that it has been called "the great white plague."

It is caused by the bacillus of tuberculosis discovered by Robert Koch in 1881–1882.

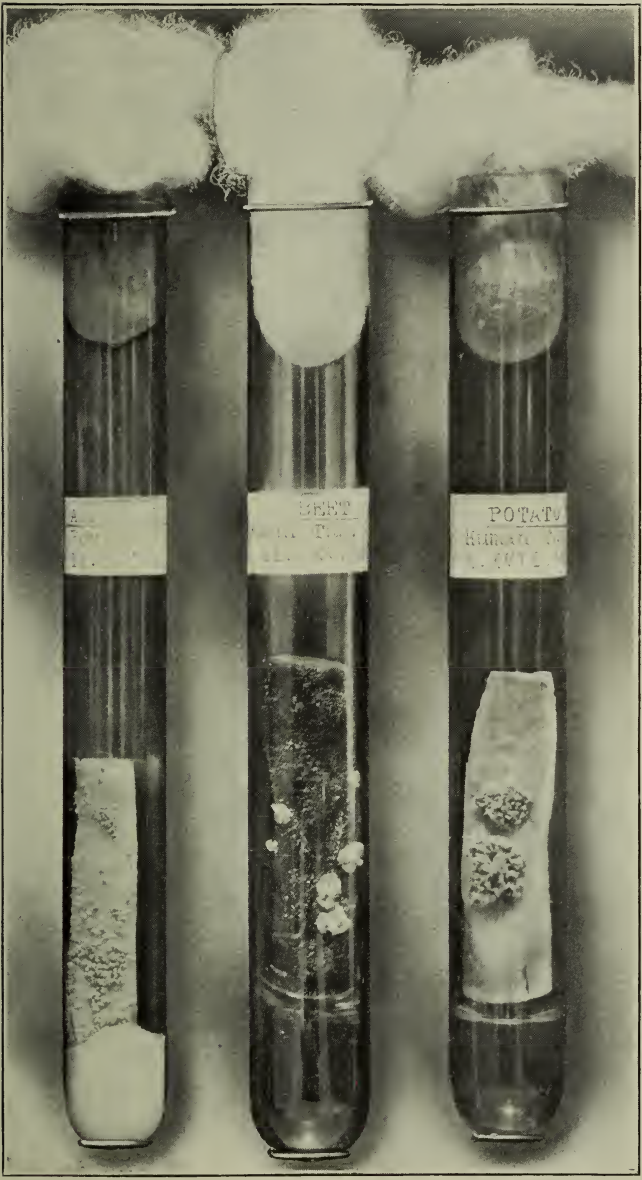
The bacillus of tuberculosis may attack almost every organ and tissue of the body, resulting in the formation of little inflammatory nodules, which have a tendency to degenerate. Tuberculosis of the lungs is commonly called consumption or phthisis; of the lymphatic glands it is called scrofula. Lupus is a tuberculosis of the skin.

The tubercle bacillus is a slender rod, inclined to be bent or irregular in shape, and beaded in appearance. It may be grown in pure culture upon potato and upon the artificial culture media used in the laboratory, but only at the body temperature, 37° C.

The tubercle bacillus does not have spores.

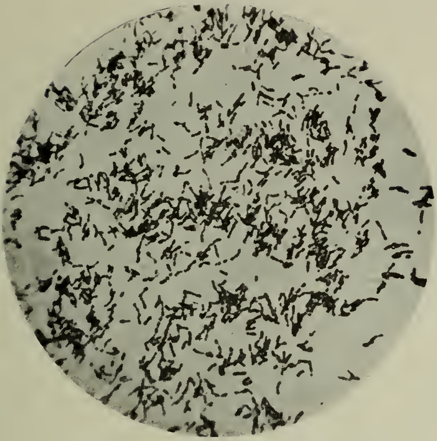
It is more resistant to heat and external influences than other bacilli. Bacterial cells without spores are usually killed by moist heat at a temperature of 56° C. in a short time, but the tubercle bacillus requires an exposure of ten minutes to 70° C. in order to kill it. It has been kept alive in sputum three years, at the end of which time it was still

Fig. 69.



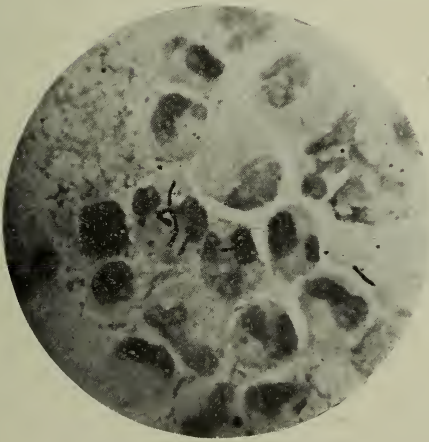
Bovine and Human Tubercle Bacillus Growing upon Vegetables.

Fig. 70.



Tubercle Bacilli, Pure Culture.

Fig. 71.



Tubercle Bacilli in Sputum.

virulent. It is therefore seen that this organism holds an intermediate place between the spore-bearing and the non-spore-bearing bacteria, so far as its resistance to external influences is concerned.

Koch believed in his first investigations that the tubercle bacillus had spores, but this observation has not been confirmed. We know that this organism does not have endogenous spores of the same high degree of resistance as anthrax or tetanus.

Tuberculosis is spread from person to person and from animals to man in a great variety of ways. The infection may be breathed into the lungs with the dust, may be taken into the alimentary canal with the food or drink, or may be inoculated into the system through wounds of the skin or mucous membranes.

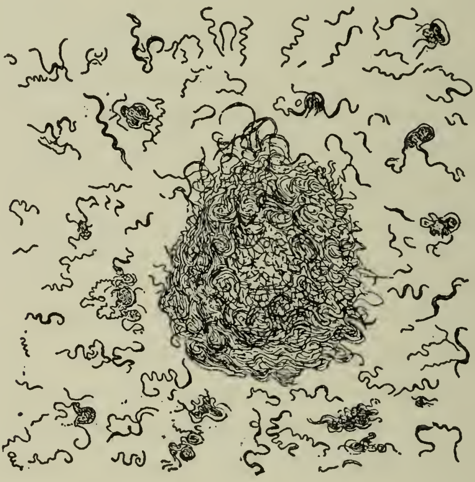
When the tubercle bacillus gains access to the tissues, it gives rise to a characteristic form of inflammation which expresses itself in the formation of little grayish nodules, called tubercles. These nodules are lacking in blood-supply and therefore have a tendency to break down and ulcerate, causing destruction of the organ or tissue in which they are situated. The process spreads through the body by way of the lymphatic channels, or more rapidly through the blood.

The tubercle bacillus is eliminated from the body in the pus and matters discharged from the processes of destructive inflammation. As the lungs are more frequently attacked than any other organ, the infection is commonly thrown off in the expectoration.

The disease is largely spread by the dried sputum which floats about the air as dust and is breathed into the respiratory tract of susceptible persons. We have already seen that the infection may remain alive and virulent a very long time in dried sputum. Kissing may also spread the bacilli from mouth to mouth. Tableware used by a consumptive is one of the means of conveying the infection to healthy persons if such ware is used without previous boiling or disinfection.

Many of the lower animals, especially cattle, are susceptible to tuberculosis, and there is little doubt but that the disease is spread to man through the agency of infected meat and milk. Tuberculous meat may be rendered safe by thorough cooking. The milk may be disinfected by boiling, or by Pasteurization, which consists in heating it to 70° C. for half an hour and then chilling it suddenly. (See page 214.)

FIG. 72.



SURFACE APPEARANCE OF A COLONY OF THE TUBERCLE BACILLI UPON COAGULATED BLOOD-SERUM.

The tubercle bacillus must be considered a hardy organism. It requires an exposure to moist heat of four hours at 55° C.

in order to kill it; or fifteen minutes at 65° C., ten minutes at 70° C., five minutes at 80° C.

It is killed at once by boiling water or steam at a temperature of 100° C. Both of these agents are trustworthy disinfectants for this infection, especially as they have the power of deep penetration. The tubercle bacillus is frequently embedded in sputum or in albuminous matter that cannot be disinfected by germicidal agents lacking penetrating power.

Drying has little effect upon this bacillus, which accounts for the dangerous nature of dried tuberculous sputum. The tubercle bacillus is not killed by freezing.

The bright sunshine will kill the organism in a few hours if exposed in a thin layer directly to the rays of the sun.

The chemical solutions in the strengths given for non-spore-bearing bacteria are efficient disinfectants for the bacillus of tuberculosis, provided there is direct contact between the germ and the chemical in solution; for example, bichlorid of mercury 1 : 1000, carbolic acid 5 per cent., tricresol 1 per cent., formalin 5 per cent.

Either formaldehyd or sulphur dioxid gas will kill this bacillus in the strengths stated for the employment of these gases in Chapter II. An exposure of no less than twelve hours to formaldehyd and twenty-four hours to sulphur dioxid is desirable, depending upon the method used to generate the gas. The gaseous disinfectants are especially useful in eradicating the infection from rooms, forecastles, and other confined places where the sputum has dried and become disseminated in the air, contaminating exposed surfaces.

The disinfection of sputum is comparatively difficult to accomplish on account of its tenacious nature and its albuminous composition. Bichlorid of mercury is totally inapplicable for this purpose, because it is precipitated by the albuminous matter which it coagulates, preventing penetration. Carbolic acid also coagulates albuminous matter, though less actively than bichlorid of mercury, and is therefore a very untrustworthy agent for the disinfection of sputum. A strong solution of formalin 15 to 20 per cent., or tricresol 2 per cent., or lysol 2 per cent., may be used to disinfect small quantities of sputum, provided they are thoroughly incorporated throughout the mass and allowed to stand no less than one hour. Chemical substances cannot compare in efficiency for this purpose with the physical agents, which should always be given the preference.

Sputum may be effectively disposed of and disinfected by burning. It may be boiled, preferably in an alkaline or soap solution; or better still, it may be disinfected with steam in a special apparatus described on page 228.

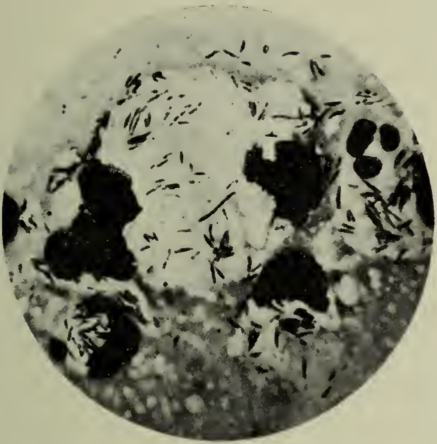
The disinfection of fabrics and other objects that have become contaminated with tubercle bacilli does not differ from the methods given for the disinfection of such materials for other non-spore-bearing infections, such as typhoid fever, diphtheria, pneumonia, etc., and need not be repeated here.

LEPROSY.

Leprosy is a communicable disease, transmitted from the sick to the well with difficulty. It is a disease of great antiquity and at present is widely distributed throughout the world, especially in warm climates. The disease is remarkable for the long time it takes to develop and the chronic course it runs.

Leprosy is characterized by the formation of nodules not unlike those of tuberculosis. These nodules, or tubercles, sometimes appear along the course of the nerves, causing

Fig. 73.



Bacillus of Leprosy in Tissue.

disturbances of sensation and giving rise to the so-called anesthetic variety. When the nodules appear in the skin or in the mucous membranes, they give rise to tubercular leprosy. These nodules have a tendency to break down and ulcerate, causing a destruction of tissue, just as in tuberculosis.

The disease is caused by the *Bacillus lepræ,* discovered by Hansen in 1879. The bacillus of leprosy resembles the bacillus of tuberculosis so very closely that it is difficult to distinguish the one from the other. The bacillus of leprosy does not attack the internal organs of the body, and has a different arrangement in the cells from that of the tubercle bacillus; it stains more readily and cannot be made to grow upon artificial media.

So far as known this bacillus does not have spores.

The disease may be transmitted from the sick to the well by inoculating into the skin or mucous membranes the material containing the bacillus. The organism is found in great numbers in the pus and secretions from the broken-down nodules and ulcers of the disease, and in all the lesions of leprosy. They may also be found in the blood. As the nodules and ulcers frequently appear upon the mucous membranes of the nasal cavity, the secretions from the nose may be infective, and it is believed that this is often the case before there are any outward signs of the affection.

So far as known, the principles of disinfection for leprosy are precisely the same as for tuberculosis, which it so closely resembles. (See page 280.)

MALARIA.

Malaria is a communicable disease causing great havoc in many parts of the world.

The malarial diseases are due to a minute animal parasite, the *Hæmatozoa malariæ,* discovered by Lavaran in 1880. This organism is a microscopic cell having independent motion and all the functions of animal life. It multiplies by a process of division common to these lower forms of life. It also reproduces by a sexual union. There are several varieties of this parasite which produce the various clinical forms of the disease, known respectively as tertian malarial fever, having chills every third day; quartan malarial fever, having chills every fourth day; and æstivo-autumnal malarial fever, having an irregular febrile course.

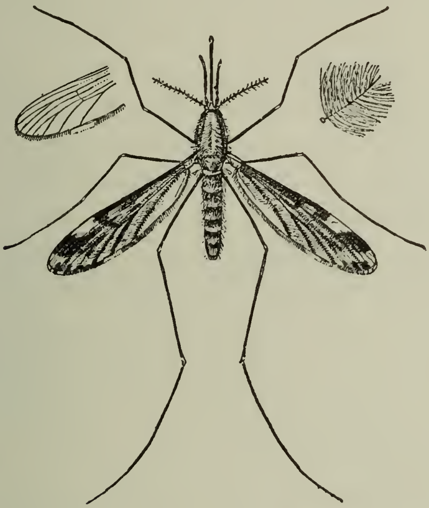
All the malarial parasites belong to the protozoa, and to the group known as the sporozoa, because they have spores during one phase of their evolution; and to the subdivision hematozoa, because they are found in the blood.

The malarial organisms are found in the blood, spleen, or other organs of the body in all cases of the disease.

Malarial infections are conveyed from the sick to the well by the mosquito. This insect takes the parasite into its stomach along with the drop of blood. In the mosquito the parasite passes through a long and complicated series of changes, taking about twelve days from the time it drinks the malarial blood until it is capable of transmitting the infection by biting another person. From the stomach of the mosquito the parasite passes into the general body cavity of the infected insect and finally appears in the veneno-salivary glands. These glands excrete the poison that is injected through the proboscis of the insect into the skin of the person it bites, and it is in this way that the malarial parasites are inoculated into the system. The mosquito itself apparently feels no ill effects as a result of the infection, for the infected insect lays its eggs and continues to feed and live in a normal manner.

Malaria is primarily a blood infection. After a few of the parasites have been introduced into the blood by the mosquito, they grow and multiply in such enormous numbers that in twelve days they may be present in countless myriads. Just before the chill more than half the red blood-corpuscles may contain one of the parasites which live and feed upon these corpuscles as well as in the blood-serum itself. In the malignant forms of malaria known as "congestive chills" the parasites are found crowded in the capillaries of the brain, liver, spleen, and other organs of the body.

FIG. 74.



ANOPHELES PUNCTIPENNIS. FEMALE, WITH MALE ANTENNA AT RIGHT, AND WING TIP SHOWING VENATION AT LEFT (ENLARGED).—(*Howard.*)

Not all mosquitos are capable of thus transmitting the infection of the malarial diseases. It is only the variety known as the *Anopheles* that is endowed with this special property.

The anopheles is a medium-sized mosquito of a brownish color, frequently having a speckled wing. The palpi are quite as long as the proboscis in both the male and female, which serves to distinguish it from the common culex varieties, and from the *Stegomyia fasciata*, which is responsible for the spread of yellow fever.

It is only the female insect that is capable of transmitting the disease. After feeding upon blood it lays its eggs upon the surface of the water. In a few days, depending upon the temperature and other conditions, each egg hatches a larva, and these develop into pupæ. The larvæ and pupæ, commonly called ''wrigglers,'' must come to the surface of the water to breathe. This is why a film of oil on the water will soon kill the embryonal forms of the mosquito.

Malaria is practically always spread by the agency of the mosquito. The only other way in which it is known that the disease may be communicated from man to man is by the direct inoculation into a well person of the blood of a patient suffering with the disease. While this has been done several times in scientific studies, it, of course, is not a method by which we could contract the infection spontaneously.

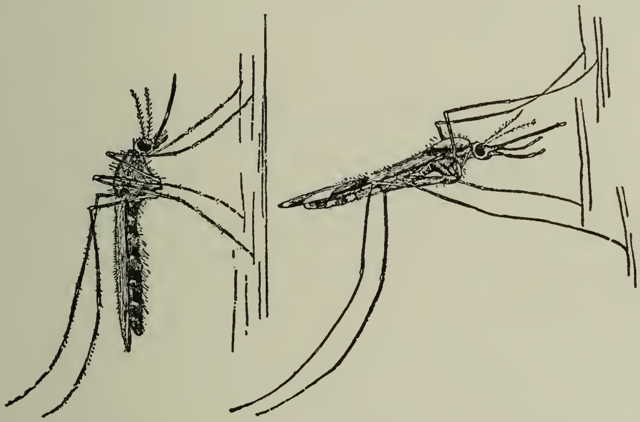
It is therefore plain that the disinfection for malaria must be directed against the infection in the mosquito.

Patients infected with malaria should be given quinin at once and carefully protected with mosquito netting or by other means in order to prevent the spread of the infection. This is manifestly impossible to carry out rigorously except with the bed-ridden patients, in a malarial region, for there are many in such regions who have the parasites in their blood, but are able to be about.

A precaution for individuals residing in malarial regions is to sleep in rooms thoroughly screened against the mosquitos. As the anopheles is largely nocturnal in its habits, this furnishes a measure of protection against the disease.

The mosquitos found in the bedroom of the sick and the well should be destroyed. For this purpose pyrethrum, sulphur dioxid, tobacco smoke, and the other insecticides recommended in Chapter IV may be used.

FIG. 75.



RESTING POSITION OF CULEX (AT LEFT) AND ANOPHELES (AT RIGHT) (ENLARGED).—(*Howard.*)

The extermination of the mosquito would mean the extermination of malaria as far as man is concerned. The anopheles is not a domestic mosquito in the sense that the yellow fever mosquito is. That is to say, it does not breed in the small collections of water found in casks, barrels, buckets, tin cans and the like about the household. It rather prefers the small natural puddles and ponds of still water, found in the fields and swampy places, to lay its eggs. The fight to exterminate these insects is one requiring a considerable expenditure of time and money, and must be vigorously carried on with unceasing patience. The means employed to accomplish this result in a given locality consist of draining the soil, often involving extensive engineering operations, and other means beyond the scope of this book.

It is evident that insecticides and not germicides are wanted to combat this disease. The ordinary methods of disinfection employed to destroy the infection of bacterial diseases are totally inapplicable for malaria.

YELLOW FEVER.

Yellow fever has its home in the West Indies, Central America, and the west coast of Africa. From these endemic foci in the tropics it spreads from time to time to the temperate regions, where it occurs in epidemic form, sometimes with great mortality.

Yellow fever is an acute febrile disease, characterized by congestions, jaundice, vomiting, prostration, and albumin in the urine. The vomited matter is often of a dark brown or black color, the so-called black vomit.

The period of incubation is commonly two to three days, rarely over five.

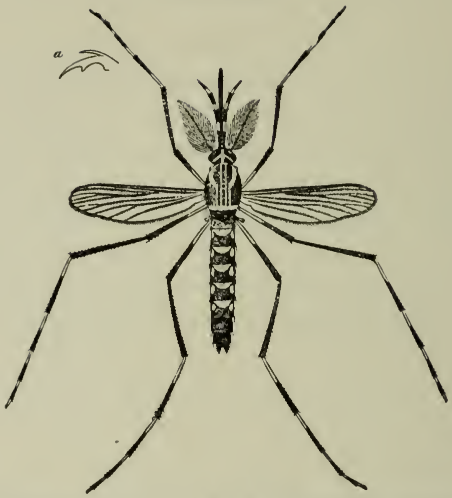
The cause of yellow fever has not been definitely determined, although there can be no doubt, from its infectious nature, that it is due to a living entity. Despite the fact that we have no definite knowledge as to the precise micro-organism that is responsible for the disease, we now have in our possession very definite information as to how it propagates itself and the methods necessary to prevent its spread. Yellow fever is not "contagious" in the sense that smallpox is; that is to say, the disease is not transmitted directly from the sick to the well. It has also long been known empirically that the infection is not spread by means of water and food, as is the case with cholera and the intestinal infections. It has been a matter of observation that houses or places become infected under certain conditions after the lapse of a given interval of time, usually several weeks. More accurately, the second case of yellow fever never occurs until twelve days have elapsed after the first case was brought to a given place.

This gave rise to the "place infection theory," and was explained upon the ground that, while yellow fever is not directly "contagious" from the patient to the well, it is "infectious" in the sense that it has the power to infect the surroundings, so that the disease is communicated in an indirect manner.

We now know, from Finlay, proved by the brilliant researches of Reed and his colleagues, that it is not the bedding, or the clothing, or the soil, or the walls of the room, or any inanimate object in the room that retains the infection, but a certain species of mosquito that, after biting the patient, takes the infected blood into its stomach. The mosquito itself becomes infected and, after the lapse of twelve days, can communicate the disease by biting another person.

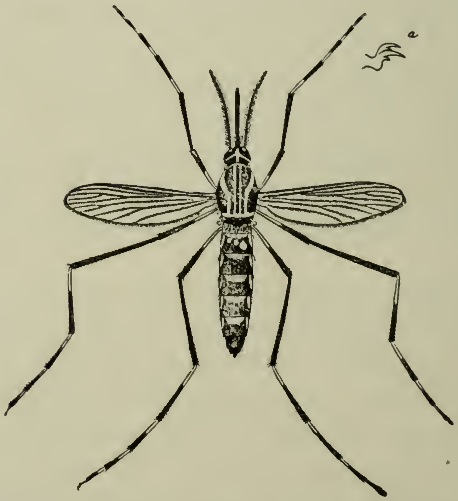
The particular mosquito responsible for the spread of yellow fever is called the *Stegomyia fasciata*. It is a rather small insect and may be recognized by the fact that it is of a light brown color with very beautiful silver markings upon its body and legs. At each tarsal joint there is a silvery-white band, and on the back of the thorax there are four bands arranged in a characteristic manner, resembling a lyre with two strings. In the female the palpi are much

Fig. 76.



Stegomyia fasciata, Male.—(*Reed and Carroll.*)
a. Front tarsal claw.

Fig. 77.

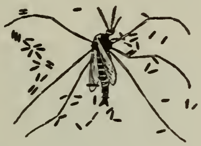


Stegomyia fasciata, Female.—(*Reed and Carroll.*)
a. Front tarsal claw.

shorter than the proboscis. It is only the female that is able to transmit the disease.

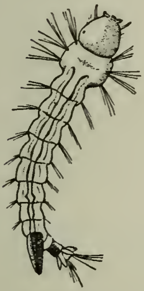
The female, after impregnation, lays its eggs upon the water. In a few days, depending upon the temperature and other conditions, the eggs hatch into larvæ and, after another interval of several days, the larvæ develop into pupæ. Both the larvæ and pupæ, popularly called wrigglers, are aquatic, but must come to the surface in order to breathe. From the pupæ finally emerge the fully developed winged insects. The fact that the mosquito lives in the water during its early existence gives us the keynote for its extermination.

FIG. 78.



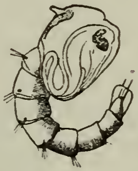
STEGOMYIA FASCIATA. BATCH OF FIFTY-TWO EGGS DEPOSITED BY A SINGLE FEMALE.—(*Reed and Carroll.*)

FIG. 79.



FULL-GROWN LARVA (ENLARGED). —(*Reed and Carroll.*)

FIG. 80.



PUPA (ENLARGED).—(*Reed and Carroll.*)

The aquatic forms of the Stegomyia fasciata, popularly called "wrigglers."

For many years it was taken for granted that fomites or inanimate objects could retain the infection of yellow fever and, after the lapse of time, transmit the disease to susceptible individuals. The literature is full of examples, accusing clothing, bedding, household furniture, a lock of hair, coffee sacks, and the greatest variety of other objects, of bringing the infection into a locality. It would seem, from our present knowledge, that these observations were based upon error.

The only known method by which yellow fever may be transmitted from the sick to the well, excepting through the agency of the mosquito, is by the direct inoculation of the blood of a patient sick with the disease into the system of a susceptible individual. This has been done in several instances in scientific research upon the cause of the disease and the methods of its transmission, but, of course, is not a method by which we would contract the disease spontaneously.

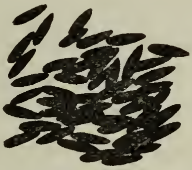
The close resemblance between yellow fever and malaria, so far as their methods of spread are concerned, is very striking.

In 1897 the Italian savant, Sanarelli, found an organism associated with cases of yellow fever, which he termed *Bacillus icteroides*. Sanarelli and others believe this bacillus to be the cause of yellow fever, although it seems difficult to reconcile this belief with the fact that the mosquito carries the infectious agent from the sick to the sound.

The Bacillus icteroides is a short, actively motile rod, growing well at both room temperature and in the incubator, at 37° C., upon the ordinary culture media used in the laboratory. It holds an intermediate place between the colon bacillus and the typhoid bacillus. In the light of our present knowledge we must consider this organism a complication sometimes associated with yellow fever rather than the cause of the disease, just as the virulent streptococci, which so frequently are found associated with smallpox, are not regarded as causing that disease.

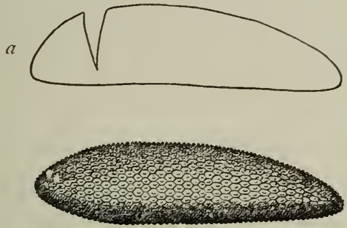
It is, therefore, evident that the disinfection of clothing, baggage, bedding, rooms, and objects that have come in contact with the patient, for the purpose of destroying a bacterial infection, is an unnecessary procedure so far as yellow fever is concerned. Insecticides, not germicides, are wanted.

FIG. 81.



STEGOMYIA FASCIATA. FORTY-EIGHT EGGS DEPOSITED IN A CLOSE-LYING MASS BY THE STEGOMYIA FASCIATA (ENLARGED).—(*Reed and Carroll.*)

FIG. 82.



NEWLY DEPOSITED EGG OF STEGOMYIA FASCIATA (ENLARGED).
a. Empty shell from which larva has escaped.

Cases of yellow fever must, therefore, be treated in rooms carefully screened against the mosquito, and all such insects found in the sick-room or in the house and neighborhood must be immediately destroyed. This may be accomplished by burning pyrethrum, sulphur dioxid, tobacco smoke, formaldehyd, or one of the other insecticidal agents recommended in Chapter IV.

The *Stegomyia fasciata* is a domestic mosquito, preferring the little collections of water about the household in which to lay its eggs. They breed in great numbers in the fresh-water cisterns and rain barrels or in the water of a tin can or bucket that may be in the back yard. It is beyond the province of this book to discuss in detail the extermination of the mosquito. Suffice it to state here that this is best accomplished by attacking the insect during the aquatic phase of its existence. All collections of water in which mosquitos may breed must be removed. This sometimes involves extensive draining and engineering problems, although, so far as the *Stegomyia fasciata* is concerned, it must be attacked in the collections of fresh water found in and about the household.

FILARIASIS.

Filariasis is a communicable infection found in tropical and warm countries, and as far north as Charleston, S. C., in the United States.

The disease is characterized clinically by chyle in the urine and by an inflammation and enlargement of the connective tissue, causing the condition known as elephantiasis.

Filariasis is caused by a nematode or worm, called the *Filaria sanguinis hominis*. The embryonic filaria probably gains access to the body by the drinking of polluted water. Upon entry into the alimentary canal the young filariæ bore through the mucous membrane and take up their abode in the deeper lymphatics. According to Manson, the mature female worm is about three inches long and about one one-hundredth of an inch in diameter, and is found packed with embryos in all stages of development.

The embryos wander into the circulating blood, and appear as tiny, actively moving, almost homogeneous worms. They are readily detected under the microscope by their vigorous, lashing movements.

There are at least three well-recognized varieties of this affection. In the one the embryos appear in the circulating blood only in the sleeping hours, usually during the night. This variety is called *Filaria sanguinis hominis nocturna.* The adult worm is called *Filaria bancroftii.* In the second variety they are found in the peripheral blood only in the daytime, and are consequently called *Filaria diurna.* The third variety is found in the circulating blood throughout the twenty-four hours, and is called *Filaria perstans.*

The infection of filariasis is not transmitted from person to person directly. As is the case with many of the animal parasites of man, an intermediate host is required. Patrick Manson has shown that the intermediate host is the mosquito. This insect takes the embryos into its stomach along with the blood it drinks, and afterward contaminates the water. Later work seems to indicate that the infection may be inoculated by the mosquito directly into the system, by biting a well person. In this way the parasites are inoculated into the blood just as in the case of yellow fever or malaria.

The prophylaxis and the methods of disinfection for filariasis therefore resolve themselves into the destruction of the mosquito and the purification of the drinking-water—a combination of the measures taken to prevent malaria and typhoid fever.

Filaria medinensis, or the *Filaria dracunculus*, popularly called the guinea-worm, is another nematode infecting persons in certain hot countries.

The mature female resides in the subcutaneous and intermuscular connective tissue, especially in the lower extremities, about the foot-joint. Its presence excites inflammation and abscess formation. The embryos are eliminated in great numbers in the discharges from the inflamed area. The embryos find their way into the water of small ponds, where they enter the cyclops, a small crustacean. From here they re-enter the body either with the drinking-water or through wounds in the skin.

Disinfection to prevent the spread of the infection consists in boiling the drinking-water and in destroying the embryos as they leave the body with bichlorid of mercury or formalin.

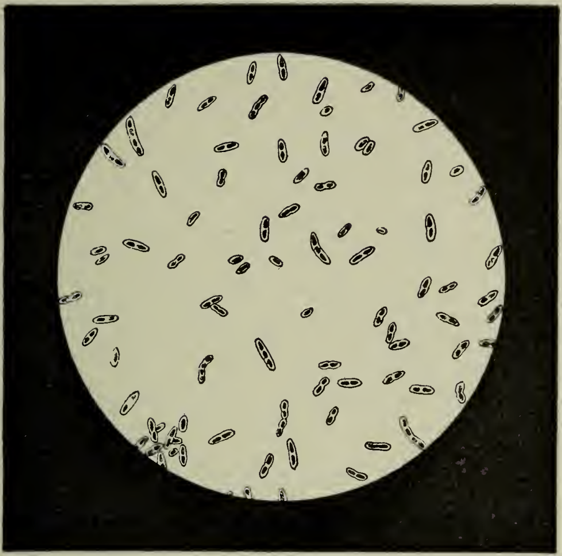
PNEUMONIA.

Pneumonia, croupous or lobar pneumonia, is one of the most widely spread of the communicable diseases. It sometimes occurs in severe epidemics with great mortality.

The disease is characterized by a specific inflammation, accompanied by a fibrinous exudate which occludes one or more lobes of the lungs. A typical case has a sudden onset with a chill and fever. There is cough with expectoration of blood-stained sputum, pain in the side, and difficulty of respiration. The fever terminates as suddenly as it appeared—that is, by a crisis.

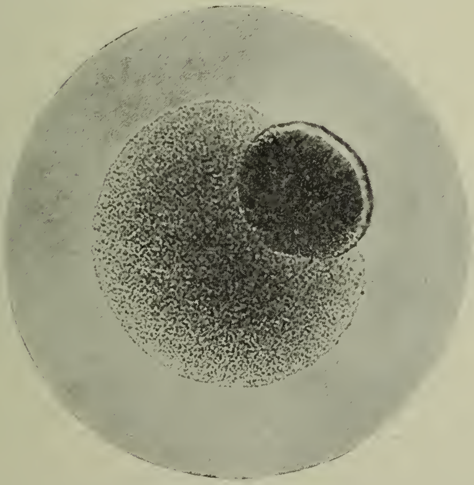
The cause of pneumonia is a micrococcus, called the *Diplococcus pneumoniæ*, sometimes the *Micrococcus lanceolatus*, or the pneumococcus of Fränkel, who showed the relationship between the organism and the disease. This micrococcus may also cause meningitis, pleurisy, ulcerative

FIG. 83.



THE DIPLOCOCCUS OF PNEUMONIA, SHOWING CAPSULES.

FIG. 84.



COLONY OF THE DIPLOCOCCUS OF PNEUMONIA ON GELATIN. —(*Fränkel and Pfeiffer.*)

endocarditis, sore throat, and other inflammatory affections that may complicate pneumonia, or may occur as independent diseases.

The diplococcus of pneumonia does not have spores.

The infection of pneumonia is probably always taken into the system through the respiratory channels. The organism exists in the secretions of the mouth in about 20 per cent. of healthy individuals. Under certain circumstances, such as traumatism, catching cold, or other depressing influences, the microbe grows and multiplies with increased virulence, invades the lungs and sets up the disease. The diplococcus of pneumonia is found not only at the site of the inflammation, but it frequently invades the blood and may be found widely distributed throughout the system.

The infection is thrown off in the sputum, which during the course of the disease is laden with great numbers of the live and virulent germs. The infection may be eliminated in other secretions or discharges, depending upon the seat of the lesion.

The infection is spread from mouth to mouth, directly and indirectly, in a great variety of ways, just as the infections of diphtheria and tuberculosis are spread.

The diplococcus of pneumonia does not show a high grade of resistance to external influences and may readily be destroyed by the germicidal agents commonly employed against non-spore-bearing infections. In fact, this organism is difficult to keep alive outside of the body. Upon the ordinary culture media used in the laboratory it dies in a few days even under favorable conditions of temperature and moisture. When pure cultures of this organism are dried, it loses its virulence and dies in a very short time. In pneumonic sputum, however, it has been found alive and virulent after drying on cloth and being kept in the light fifty-five days. Exposed to the sunlight the same material retained its virulence only twelve hours.

A moist temperature of 52° C. continued ten minutes is fatal for the diplococcus of pneumonia. Boiling water or steam destroys the infection at once.

Formaldehyd and sulphur dioxid are efficient disinfectants for this micro-organism in the strengths and times as stated for each of these gases in another chapter.

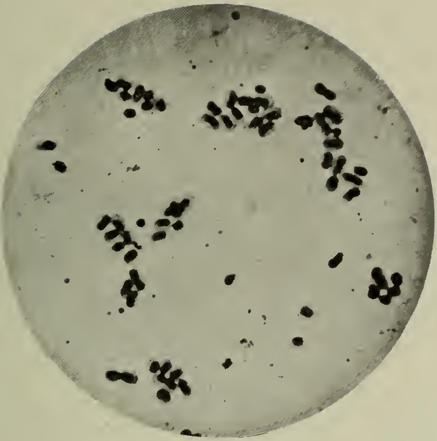
Bichlorid of mercury destroys the life of the coccus of pneumonia in as weak a dilution as 1 : 20,000 in two hours. In the usual strength, 1 : 1000, its action is almost instantaneous. Solutions of bichlorid of mercury are not applicable to the destruction of the infection in the sputum, because it is precipitated by and cannot penetrate albuminous matter. (See pages 152 and 226.)

Carbolic acid in a 1 per cent. solution restrains the development of the diplococcus of pneumonia, and in a 3 to 5 per cent. solution kills the organism in a short time. Tricresol 1 per cent., formalin 3 to 5 per cent., and other chemical solutions recommended for the destruction of non-spore-bearing bacteria, are useful for pneumonia.

In general the same principles for the disinfection for diphtheria or tuberculosis are applicable to the destruction of the infection of pneumonia, and need not be repeated.

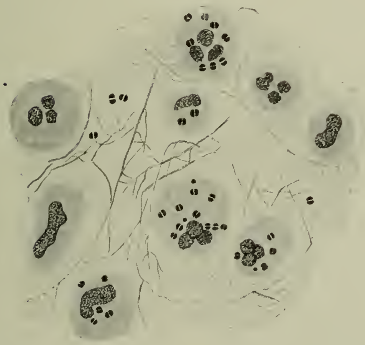
A pneumonic consolidation of the lungs may be caused by several organisms other than the pneumococcus of Fränkel. For instance, there is a pneumonic form of plague, diphtheria, influenza, typhoid and other fevers, resulting from the growth and irritating presence of the respective organisms of these diseases. The pneumobacillus of Friedländer shown in the accompanying illustration (Fig. 85) is occasionally associated with an inflammation of the lungs, and was at one time believed to be the true cause of croupous pneumonia.

Fig. 85.



Friedländer's Bacillus of Pneumonia.

Fig. 86.



Diplococcus intracellularis meningitidis in Pus-cells.—(*Councilman.*)

EPIDEMIC CEREBRO-SPINAL MENINGITIS.

Cerebro-spinal meningitis is a communicable disease, sometimes occurring in very fatal epidemics. The disease is characterized by an inflammation of the membranes of the brain and the spinal cord which gives rise to a great variety of symptoms.

The cause of the infection is a micrococcus, called the *Diplococcus intracellularis meningitidis*. This organism is a diplococcus and is found for the most part in the cells of the inflammatory exudate. It resembles the diplococcus of pneumonia very closely in many particulars.

It has no spores.

The disease is evidently not directly contagious from the sick to the well, nor is the infection transmitted upon the clothing. As the diplococcus causing the disease is only found associated with the inflammation locked up in the cranial cavity and the spinal canal, it is difficult to understand how the infection leaves the body of the sick and enters the system of the sound. The infection is not found in the excretions from the body, so long as the membranes of the brain and spinal cord remain intact. It has been suggested that the micro-organism gains entrance into the body through the mucous membrane of the nose. Flexner and Barker suggest that the infection may gain entrance into the system through the intestines, but these views do not seem compatible with the rapid extension of some epidemics of the disease.

So far as we know, the diplococcus of cerebro-spinal meningitis is a very frail organism outside of the human body; in fact, it is very difficult to keep it alive and growing upon artificial culture media. It is killed very readily when dried or in contact with heat or weak disinfecting solutions.

So little is known of the existence of this infection in nature outside of the body and the channels through which it gains entrance into the system that we cannot apply our disinfectants with any assurance of limiting the spread of the disease. Our hope in a case like this is to practise a general disinfection of all the discharges, and all the objects that come in contact with the patient, and to give the room a general purification with formaldehyd after the termination of the case. The windows should be screened against insects. In this way we apply all the known principles with the expectation that by a shotgun method we will strike the mark.

SMALLPOX.

Smallpox, variola or varioloid, is a highly communicable disease known since times immemorial in China and India. It was brought to this country by the Spaniards in the sixteenth century.

Smallpox is an acute febrile disease characterized by an eruption which is first papular, then vesicular. The vesicles either dry up and disappear (varioloid), or they turn to pustules and crusts (variola).

The period of incubation is a very constant factor in smallpox. The disease makes its appearance between the tenth and the fourteenth day following exposure, usually the twelfth day. Cases have been reported in which the stage of incubation has been as short as five days and as long as twenty days. When the virus is inoculated into the skin (variolation), as was formerly done as a prophylactic measure, the local reaction resembling vaccinia appears at the point of inoculation on the third or fourth day, but the general symptoms and fever do not appear until the eighth day, and the general eruption on the eleventh day following the inoculation.

The cause of smallpox is not known. It is the type of the acute specific infections, and there can be no doubt but that the disease is caused by a living entity or micro-organism. Fortunately we know the disinfecting agents and their strengths necessary to kill the infectious principle whatever it may be. So certain has our knowledge become that only wilful negligence or ignorance will permit smallpox to become epidemic in a community. In short, vaccination, isolation of the sick, and disinfection will certainly prevent the spread of the disease.

Smallpox has long been considered a "contagious" disease because it is more readily conveyed by contact between the sick and the well than any other of the communicable diseases of man. We know that the specific virus is thrown off from the patient into the surrounding air, perhaps with the exhaled breath, and certainly from the eruption, whether fluid or dried in the crusts. It is probable, though not proved, that the virus is contained in the blood, but not in the excreta.

It is believed that the virus usually enters the system through the respiratory tract—that is to say, the infection is air-borne. The disease may also be caused by introducing some of the fluid secretions of the vesicles or pustules into the skin of a susceptible person. Variolation, which was formerly practised, has given us abundant proof that such material inoculated into injured parts of the skin will reproduce the disease in all its essential characteristics.

Smallpox spreads chiefly through the medium of the sick, more rarely of intermediate persons. It is definitely known that inanimate objects which have come in contact with the patient or the infectious discharges may retain the infection alive and virulent, and communicate the disease to others even after the lapse of a very long time. For example, blankets, bedding, and clothing which have been used by the patient and afterward packed away without any disinfection have caused the disease in another person who has unpacked or handled these objects months afterward. Well-authenticated instances are on record where the infection has remained on fomites (inanimate objects) for two years and then given rise to the disease, showing the great vitality of the virus under certain conditions.

As far as disinfection for smallpox is concerned, we must be guided largely by the results of practical experience and analogy to other communicable diseases, especially vaccinia, which is considered a modified form of smallpox, and for our purposes may be regarded as the same disease. Researches have shown that the virus of vaccinia is destroyed by heat at a temperature of 54° C. in a short time, also that sulphur dioxid is efficacious in destroying the potency of the virus. We know how very susceptible this virus is to the ordinary germicidal solutions. Therefore it is reasonable to suppose that the active principle of smallpox, whatever it is, may be destroyed by the same disinfecting agents that are used for non-spore-bearing infections, such as diphtheria, tuberculosis, cholera, typhoid fever, etc. In fact the application of the principles of disinfection based upon this supposition meets with success in actual practice.

The disinfection for smallpox must begin at the bedside. It is believed by some that the disease is communicable even before the eruption appears. It is important to keep the skin of the patient clean and anointed with a bland oil or salve to prevent the desquamating epiderm and the dried secretions of the eruption from floating into the air. A disinfectant may with advantage be added to the oil or ointment. For this purpose a carbolized vaselin, or olive oil, or a borated or salicylated lard is very useful. The skin may be bathed from time to time with a weak solution of bichlorid or carbolic acid, or one of the hypochlorites. Such measures are grateful to the patient and are a decided help in destroying the superficial infection and of preventing it from leaving the body in a live and active form.

As the eruption frequently appears upon the mucous membranes, especially of the mouth and throat, the sputum may be contaminated and should be disinfected. The urine and the excreta are not believed to contain the virus, but as they are very apt to become contaminated with the infection from the skin and other sources, they should be disinfected by the methods given for these substances in another portion of this volume. The vessels containing these excretions must be carefully disinfected.

Smallpox is very apt to be complicated with abscesses and ulcers upon the skin. These sores often suppurate for a long time and the pus discharged from them contains the virus of the disease, and must therefore be disinfected.

The hair will need particular attention to prevent the desiccation and diffusion of the crusts and flakes of epiderm. If the hair is long and the eruption abundant upon the scalp the hair had better be cut to prevent the matting and decomposition of the crusts. In the cutting care should be taken to prevent particles flying about by keeping the hair moist, and gathering it all together in a cloth wet with bichlorid 1 : 1000 and the whole immediately burned.

The infection of smallpox is so readily diffused that not only the objects coming in contact with the patient and his discharges will need treatment, but the entire room and its contents must be disinfected. The room in which the patient is treated should contain only the necessary articles, and all carpets, hangings, upholstered furniture, and other objects not necessary for the care and comfort of the patient should be removed. The windows should be screened to prevent the ingress and egress of flies and other insects, for it is reasonable to suppose that flies which come in contact with the eruption may convey the infection on their feet and smeared upon their bodies, to persons in other rooms of the same house or to other houses. It is also well to keep a sheet wet with a solution of bichlorid hanging in the doorway leading from the sick-chamber, and to restrict the communication with the sick-room to a minimum.

The room in which a case of smallpox is treated should have all its surfaces mopped at least once a day with an antiseptic solution such as bichlorid 1 : 1000, and dry sweeping and dusting must be prohibited, as well as anything which has a tendency to raise the dust.

The towels, bedding, body linen, clothing, and other fabrics which have in any way come in contact with the patient or the infection, should be gathered in a sheet wet with a bichlorid solution, and then immediately boiled, steamed, or immersed in one of the disinfecting solutions.

The disinfection of the room and its contents after contamination with a case of smallpox may best be accomplished with one of the gases, either formaldehyd or sulphur dioxid being available for this purpose.

These gases cannot be depended upon for more than a surface disinfection; therefore carpets, hangings, clothing, bedding, upholstered furniture, and other objects needing deeper penetration to purify them must be removed for other treatment appropriate to each object as described in another section. The preparation of the room for the gaseous disinfection is very important and has been described in another place, page 84. In removing objects from the room for disinfection care must be taken to carefully wrap them in a sheet wet with bichlorid solution, or, if this is not practicable, to thoroughly disinfect the surface of the object by washing it down with one of the antiseptic solutions.

CHICKEN-POX.

Chicken-pox, or varicella, is an acute communicable disease frequently occurring in epidemics among the children. The disease has no relation to smallpox. It is characterized by a febrile condition and an eruption of vesicles upon the skin.

The cause of chicken-pox is not known.

The period of incubation is ten to fifteen days.

The disease is highly "contagious" in the same sense that smallpox is—that is, by contact between the sick and the well.

As far as disinfection is concerned, precisely the same methods and agents recommended for smallpox are applicable to this disease.

MUMPS.

Mumps, or epidemic parotitis, is a communicable disease, sometimes occurring in epidemic form. It is characterized by an inflammation of the parotid gland.

The cause of mumps is not known.

The period of incubation is from two to three weeks.

The disease is communicated from the sick to the well, but how has not been determined. It is supposed that the saliva contains the infective principle, and therefore handkerchiefs and other fabrics and objects which come in contact with the secretions from the mouth should be disinfected.

MEASLES.

Measles is a highly communicable disease occurring in epidemics. It is characterized by a fever, catarrhal symptoms, especially of the mucous membranes of the respiratory tract, and by a rapidly spreading eruption with desquamation of the epidermal layer of the skin.

The period of incubation is usually about ten days, but may be as long as twenty days.

The cause of measles is not known. From observations made it is very probable that the specific agent is thrown off in the breath of the affected person; in other words, this may be one of the few air-borne infections. The disease is communicated by the secretions, particularly that of the nose, and there is no doubt but that the desquamating epithelial flakes may transmit the infection. In these respects measles resembles smallpox very closely so far as the methods and channels of infection are concerned.

As with smallpox, the infection may also be conveyed through a third person, or by fomites—that is, inanimate things.

The disinfection for measles is precisely the same as that described in detail for smallpox and need not be repeated here. (See page 312.)

SCARLET FEVER.

Scarlet fever is a communicable disease occurring in most large communities and from time to time breaking out in epidemic form, especially among the children. The disease is characterized by a sore throat, a diffuse eruption and desquamation of the epidermal layer of the skin, frequently in large flakes.

The cause of scarlet fever has not been determined.

The period of incubation is very variable and not well determined. It may vary from three to twelve days.

The disease is communicated directly from the sick to the well, probably through the agency of the fine scaly particles which are diffused with the dust throughout the room. The infectious principle is probably not given off until the eruption appears, and there is no doubt that the specific agent is found in and spread by the desquamating skin, and also the sputum. The infection clings with great persistence to clothing of all kinds and to articles of furniture and other objects in the room. In this respect the infection of scarlet fever resembles that of smallpox very closely. Bedding and clothing that have been put away for months and even for years may, unless thoroughly disinfected, convey the infection. Physicians, nurses, and others in contact with the patient may carry the infection to persons at a distance.

Epidemics of scarlet fever have also been traced to the milk, and there is little doubt but that this fluid may be responsible for the spread of the disease.

As far as the disinfection for scarlet fever is concerned, we must be guided wholly by analogy and by experience. As the disease is spread largely as diphtheria and smallpox are spread, we have applied the same agents and principles for the disinfection of scarlet fever as for these diseases.

WHOOPING-COUGH.

Whooping-cough is a communicable disease, characterized by paroxysmal spells of coughing that end with a peculiar inspiratory "whoop." The disease occurs in widespread epidemic form and is frequently fatal, especially in young children.

The cause of whooping-cough is not known.

The period of incubation is variously stated as from two to ten days.

The disease is communicated directly from the sick to the well through the secretions of the mouth and the respiratory tract as in the case of diphtheria. There is also reason to believe that the virus from this source may be harbored upon handkerchiefs and towels, in clothing and bedding, and upon furniture and objects in the room, and transmit the disease to other persons.

So little is known as to the cause of whooping-cough and the precise method of its spread that we have no accurate scientific data upon which to base our disinfection.

All handkerchiefs, towels, eating utensils, and other objects which come in contact with the secretions of the mouth should be boiled or steamed. The room in which the patient is isolated should be frequently mopped with a solution of bichlorid 1 : 1000 or carbolic acid 3 per cent. After the symptoms have disappeared the room should be given a general disinfection with one of the gases, either formaldehyd or sulphur dioxid. These measures are based upon general principles and analogy to similar infections of a known nature.

INFLUENZA.

Influenza is a highly communicable disease, occurring in widespread epidemics. It spreads with greater rapidity than any known infection. In a few weeks a whole continent may be involved.

The disease is characterized by fever, catarrhal inflammation of the mucous membranes, and prostration. The symptoms are very inconstant.

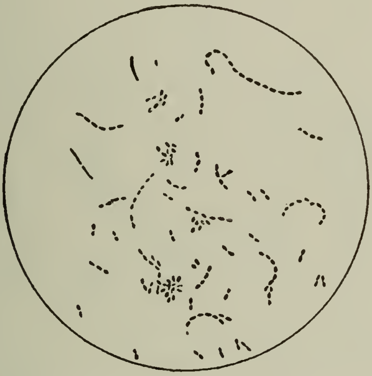
The period of incubation is stated as from one to four days, oftenest three to four days.

The cause of influenza is believed to be the bacillus described by Pfeiffer in 1892. It is a very slender, non-motile rod, growing with difficulty upon the culture media used in the laboratory.

It does not have spores.

The disease is "contagious" in the sense that it is communicable by contact between the sick and the well. The infection spreads along the lines of travel. It was believed that the disease has the power of spreading quicker than railroad trains or ships could convey the sick or the infectious material, and it was therefore assumed that the causative agent was in the air and was conveyed from place to place as a result of certain ill-defined meteorologic conditions. This, however, is probably not the fact. The disease has apparently been limited and kept from institutions by isolation and other precautions, including disinfection.

FIG. 87.



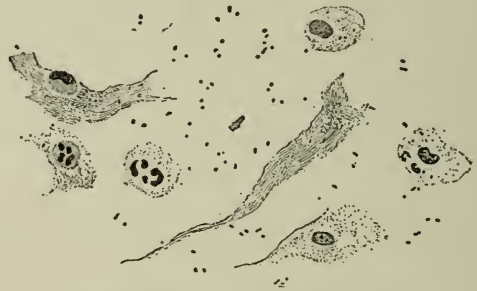
INFLUENZA BACILLUS.—(*Curtis.*)

The infection is probably taken into the system through the respiratory tract, although there is little definite evidence to prove this assumption.

The bacillus of influenza is found in great numbers in the secretions from the mouth and nose of those suffering with the disease, and the infection is chiefly eliminated through these channels. The bacillus is not found in the blood.

The bacillus of influenza is a very frail organism outside of the body; in fact, it is very difficult to keep it alive upon culture media, even under the most favorable conditions of moisture, temperature, etc. It dies quickly when dried, whether in pure culture or in sputum. A moist temperature of 60° C. will destroy the infection in ten minutes; boiling water or steam, at once.

FIG. 88.



INFLUENZA BACILLUS IN SPUTUM.

It is extremely susceptible to germicidal agents when exposed in pure culture. Formaldehyd and sulphur dioxid are trustworthy disinfectants in the strengths and times as stated for the employment of these gases.

The chemical solutions in their ordinary strengths as employed for non-spore-bearing infections will kill the bacillus of influenza; for example, bichlorid of mercury 1 : 1000, carbolic acid 3 to 5 per cent., tricresol 1 per cent., formalin 3 to 5 per cent.

The disinfection for influenza resembles that recommended for diphtheria or tuberculosis, especially as the infection is largely thrown off from the body in the expectorated matter, and the principles and methods described for those diseases are applicable to this infection. For the treatment of the sputum see page 226. The handkerchiefs, towels, bedding, and other fabrics that come in contact with the infection should be boiled, steamed, or immersed in one of the germicidal solutions mentioned above.

As the infection of influenza is evidently readily diffused into the air, the sick-room should be given a general purification with one of the gaseous disinfectants, preferably formaldehyd.

ERYSIPELAS.

Erysipelas is a communicable disease, sometimes occurring in epidemics. It is characterized by a special inflammation of the skin, with fever and all the characteristics of an acute specific infection.

The period of incubation is variable, probably from three to seven days.

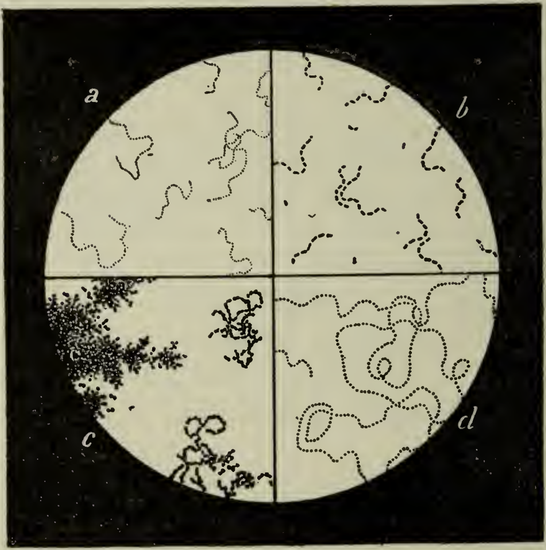
The cause of the disease is the *Streptococcus erysipelatis*, or the *Streptococcus pyogenes*, sometimes called the micrococcus of Fehleisen, who first obtained this organism from the skin of cases of erysipelas in 1883. It grows in chains of minute spherical cells, and can be cultivated at the body temperature only with difficulty upon culture media.

The micrococcus of erysipelas does not have spores.

It is always found in the inflamed region, especially in the spreading zone of inflammation. The organism usually remains localized at the seat of the lesion, but it may invade the blood and with its toxin give rise to serious and often fatal complications.

It is believed that the infection of erysipelas always enters the system through wounds in the skin or mucous membranes. These wounds may be such slight fissures or abrasions as not to be visible to the naked eye. Before the days of asepsis and antisepsis erysipelas was a frequent complication of wounds, and was often found in epidemic form in hospitals and camps.

Fig. 89.



Various Appearances of Streptococci from Bouillon Cultures.

The infection of erysipelas is eliminated from the body in the pus and secretions from the seat of the inflammation, and perhaps also in the desquamating skin from the inflamed area.

Outside of the body the micrococcus of erysipelas is a very frail organism. It dies and loses its virulence very quickly when dried, especially in the sunshine. It is very susceptible to heat and antiseptics.

It is killed by a moist temperature between 52° and 54° C. in ten minutes. Boiling water or steam at a temperature of 100° C. destroys the infection at once.

Formaldehyd and sulphur dioxid in the strengths and time as stated for the employment of these gases are efficient disinfectants for the micrococcus of erysipelas.

It is also destroyed by the ordinary germicidal solutions in the strengths employed for the destruction of the non-spore-bearing bacteria; for example, bichlorid of mercury 1 : 1000, carbolic acid 3 to 5 per cent., tricresol 1 per cent., formalin 3 to 5 per cent.

The bandages and other dressings from a case of erysipelas should be burned or thoroughly boiled. The bedding, towels, and other fabrics that have come in contact with the patient or the infection must be boiled, steamed, or immersed in one of the germicidal solutions. The hands of the nurse and all objects that have in any way come in contact with the infected secretions must be disinfected by methods appropriate for each object.

Rooms that have become contaminated with the infection of erysipelas should be given a disinfection with one of the gases, followed by a thorough cleansing.

DENGUE.

Dengue is a communicable disease occurring in epidemic form in tropical and subtropical regions. The disease is characterized by fever, pain in the joints and muscles, and sometimes a rash.

The cause of dengue is not known.

The period of incubation is from three to five days.

The disease spreads from place to place along the lines of travel—on ships as well as railroads. The infection seems apparently to be in the air (?), for the disease is remarkable in attacking all the members of a community whether they have apparently come in contact with the sick or not. It spreads over a great expanse of territory in a very short time. Practically nothing is known of the method by which the contagion is thrown off from the body, or the channels of infection. As far as known the disease never proves fatal, and few observations have been made upon its pathology.

Disinfection is not practised to check the spread of dengue, and as long as we know so little of its nature and the conveyance of the infection, we could not hope to accomplish much with the ordinary methods of disinfection.

The recent work of Graham states that dengue is caused by an animal parasite, similar to the protozoon of malaria, and that the disease is spread by the mosquito.

TYPHUS FEVER.

Typhus fever is a highly communicable disease, formerly occurring in very severe epidemics. It is now rarely seen. Typhus fever is also called spotted fever, jail fever, camp fever, ship fever, hospital fever. It spreads, as its name indicates, in filthy, overcrowded, and unsanitary places. The disease in former years claimed many victims in Europe and this country, but since modern improvements in sanitation have been introduced into cities and institutions, and the misery of poverty has been diminished, there seems to be no tendency for the disease to spread, although it is always present in some of the large cities.

Typhus fever is an acute, specific, febrile disease, characterized by a sudden onset, severe depression, and a rash. The fever usually terminates by crisis about the end of the second week.

The cause of typhus fever is not known.

The period of incubation is given as twelve days, but it may be less.

Typhus fever is believed to be "contagious" in the sense that it is communicated by contact between the sick and the well. When the disease exists in epidemic form, it is the most highly contagious of all the diseases of man. The nurses, physicians, and those who come in contact with the patient are the first to take the disease. Few escape.

The specific virus, whatever it may be, seems to be given off into the atmosphere surrounding the patient, perhaps in the exhaled breath. Practically nothing of an exact nature is known as to how the poison is excreted from the body or how the infection is introduced into the system.

It is evident that sanitation is much more needed to prevent the spread of this disease than disinfection; in fact, while disinfection is practised for typhus fever, there is nothing to indicate that it is efficacious in preventing the spread of the disease.

RELAPSING FEVER.

Relapsing fever, also called "famine fever" and "seven day fever," is a communicable disease sometimes occurring in epidemic outbreaks. The disease is common in India, and has from time to time extensively prevailed in Europe and Ireland. In 1869 it prevailed as an epidemic in New York and Philadelphia; since then it has not reappeared in epidemic form in this country.

Relapsing fever is characterized by a sudden onset with a chill, followed by fever lasting about a week. There is then an intermission of the same length of time, followed by a repetition of the febrile paroxysm. The relapses, from which the affection takes its name, may repeat themselves four or five times.

The time of incubation appears to be very short, and in some instances the attack appears soon after the exposure. More frequently the time of incubation is five to seven days.

Relapsing fever is caused by a spiral-shaped micro-organism in the blood discovered by Obermeier in 1873, and called the *Spirochæta obermeieri*. It is an actively motile, narrow, spiral filament, found in the blood only during the fever. It has never been grown on artificial media, and nothing is known of its existence in nature outside of the body.

The channels of entrance into and the modes of elimination from the body are not known.

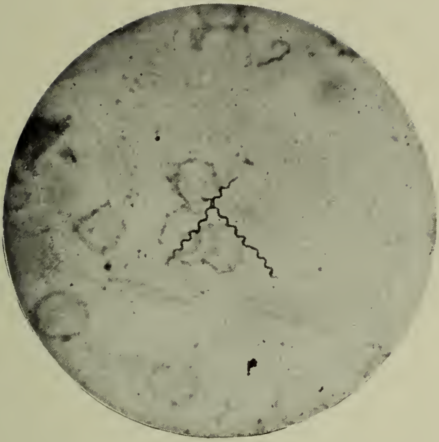
Relapsing fever develops and spreads under the same conditions that favor typhus fever. Sanitation seems to be more important than disinfection. As the disease may be transmitted by inoculating the blood of the sick into the well, perhaps biting insects convey the infection.

GLANDERS.

Glanders, or farcy, is a widespread communicable disease of horses, mules, asses, and other animals. It is occasionally communicated to man. In both man and horses it is remarkable for its fatality.

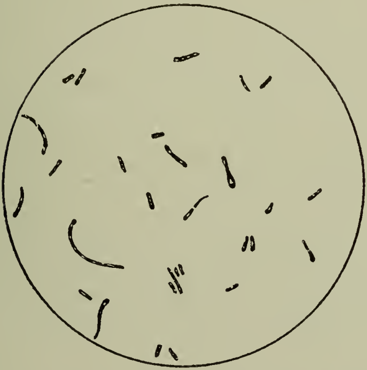
The disease is characterized by the formation of inflam-

FIG. 90.



SPIRILLUM OF RELAPSING FEVER.

FIG. 91.



BACILLUS OF GLANDERS, SHOWING IRREGULAR STAINING.

matory nodules, either in the mucous membrane of the nose (glanders) or in the skin (farcy).

The period of incubation of the acute form of glanders in rarely more than three or four days.

Glanders is caused by the *Bacillus mallei.* This organism is a slender, non-motile rod, and grows well upon the artificial culture media used in the laboratory.

It does not have spores.

The infection may be introduced into the system either through the skin or mucous membrane of the respiratory tract. In the former case the disease is usually communicated from the horse to man by contact with the infected discharges, which gain entrance into the system through wounds in the skin, giving rise to the form of the affection known as farcy. The disease is sometimes communicated from man to man. Washerwomen have become infected from the clothes of a patient. When the infection is deposited upon the mucous membrane of the nose, the form of the disease known as glanders results.

The inflammatory nodules which characterize the disease have a tendency to break down, causing ulcers and abscesses, and the infection is eliminated from the body in the pus and secretions from the seat of the lesions.

In general the bacillus of glanders is killed by the same agents used against the tubercle bacillus, which it resembles in many particulars.

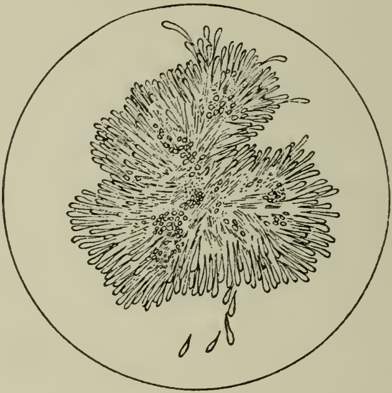
As far as disinfection to prevent the spread of the disease is concerned, the same measures that have been described in detail for diphtheria and tuberculosis are applicable to glanders.

ACTINOMYCOSIS.

Actinomycosis is a disease of man and some of the domestic animals, more especially cattle, horses, and pigs. The affection is commonly known as "big-jaw," "lumpy-jaw," or "wooden-tongue." The disease is rare in man.

Actinomycosis is characterized by a tumefaction and inflammation of the tongue and adjacent tissues of the jaw. The lips, cheeks, bones, lungs, skin, and other tissues of the body may be affected. When the infection appears in the lungs of man, the disease resembles pulmonary tuberculosis. There is also an intestinal form of the disease.

FIG. 92.



RAY-FUNGUS OF ACTINOMYCOSIS. FRESH, UNSTAINED PREPARATION FROM A CASE OF LUMPY-JAW IN A COW. DIAGRAMMATIC.—(*Williams.*)

The cause of actinomycosis is a ray-fungus, the *Actinomyces.* This organism is a streptothrix, having branching filaments. It may be grown in pure culture on the artificial media used in the laboratory.

In the pus and secretions of the lesions are found peculiar white or yellowish bodies, visible to the naked eye, that have the appearance of fine grains of sulphur or sand. Under the microscope these little bodies are seen to consist of a rosette of mycelial threads with numerous oval, spore-like bodies in the center.

How the organism enters the system is not known. It is doubtful whether the disease may be communicated from man to cattle, or from cattle to man. It seems more probable that both man and cattle receive the infection from the same external source. The infection is probably most frequently taken into the mouth with the food. In this way either the tongue or the adjacent tissues of the mouth and jaw become infected through minute wounds, abrasions, or through carious teeth. Barley and rye are looked upon with most suspicion. The fungus or its spores may also enter the system with the drinking water, to cause the abdominal form of the disease, or with the dust to cause the pulmonary form.

The irritation caused by the presence of the parasite in the tissues sets up a specific inflammation resembling tubercles. The nodules have a tendency to break down and the infection is eliminated from the body in the pus and discharges from the local lesions.

Little is known as to the resistance of the fungus of actinomycosis, or of its existence in nature outside of the body. The sputum and the dejecta in the abdominal cases should be disinfected in accordance with methods already given. The bandages and other objects which have become soiled with the discharges should be burned or disinfected with steam or boiling water. On account of the presence of spores it will be necessary to use disinfecting agents which will destroy their vitality. See Anthrax and Tetanus.

MADURA FOOT.

Madura foot is an infection occurring mostly in the province of Scinde, in India. Several cases have been recognized in this country. The disease is also called mycetoma, Madura disease, fungus foot of India, *pied de Madura.*

The disease is characterized by a specific granulomatous inflammation caused by the fungus, *Streptothrix maduræ,* similar to the ray-fungus of actinomycosis.

The fungus of Madura foot may be obtained in pure culture from the affected nodes. It grows well in acid vegetable infusions.

Upon the surface of agar strikingly beautiful, rounded, glazed colonies are formed. They become rose-colored or bright red. Under the microscope this organism is plainly seen to be a true fungus, as it has branching forms. Spores can be distinguished in the long mycelial threads.

The fungus gains entrance into the body through wounds in the skin, and by its irritating presence sets up a chronic inflammatory process. The disease is often traced to the prick of a thorn.

The feet are usually affected, sometimes the hands, and in one case that has been reported, the shoulders and hip. The onset of the affection is very insidious. Small indurated nodules form at the site of the infected part, which is frequently situated upon the pad of soft tissues forming the ball of the foot, or the thumb. These nodes gradually grow larger, until, after the lapse of months, they attain a perceptible size, sometimes to enormous growths.

Later, perhaps not until the lapse of a year or two, the inflamed and indurated mass softens and breaks down, forming abscesses and sinuses. The bones, as well as the soft parts, may be involved.

The discharge from the seat of the lesion contains small bodies resembling those found in actinomycosis. These bodies are described as resembling the grains of black gunpowder, coming from that form of the disease known as melanoid mycetoma, or resembling shad-roe, coming from the pale or ochroid variety of the disease. They consist of a dense radiate mycelium, similar to the bodies found in the lesions of actinomycosis.

The infective agent is probably eliminated from the body only in the discharges from the seat of the lesion.

The disease is probably not communicated directly from man to man. While the mode of entrance of the ray-fungus of mycetoma into the human body has not been determined with certainty, there seems little doubt but that it gains entrance by inoculation into the soft tissues, in a manner similar to actinomycosis.

The malady is often traced to wounds in the affected region.

While the fungus of mycetoma has been obtained in pure culture from the seat of the lesions, and has been grown on the culture media used in the laboratory, practically nothing is known of its existence in nature outside of the body. The strengths of germicidal agents necessary to destroy its life must be surmised from analogy to other better known spore-bearing fungus growths, as little has been done to test its resistance.

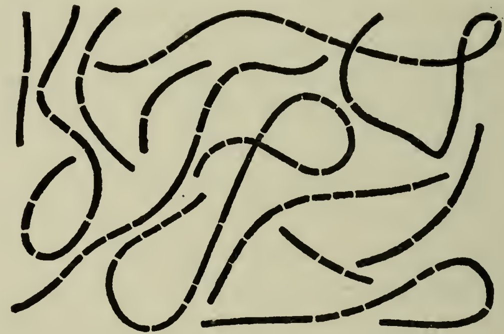
The dressings which have become soiled with the discharges should be burned. Articles which have become contaminated with the infection should be boiled, steamed, or subjected to strong germicidal solutions sufficient to kill spores, such as anthrax or tetanus.

ANTHRAX.

Anthrax is a communicable disease, occurring as a widespread infection of the lower animals, especially sheep and cattle. It is occasionally communicated to man. Anthrax is also called malignant pustule, splenic fever, charbon, and wool-sorter's disease.

The disease is characterized by a variety of symptoms depending upon the seat of the lesion. If the infection is introduced into the skin, a local reaction results causing the "malignant pustule." The inflammation spreads through the lymphatics and may invade the blood. When the infection is taken into the respiratory tract, it causes a violent inflammation resembling bronchitis or pneumonia, and is called wool-sorter's disease. Sometimes the infection is taken into the intestinal tract, producing symptoms of an intense poison. All forms of the disease frequently result fatally.

FIG. 93.

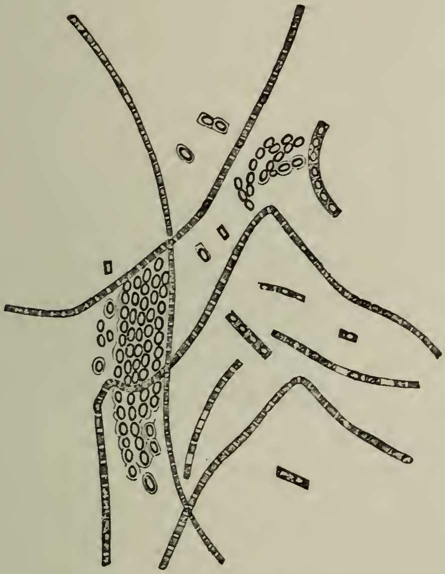


ANTHRAX BACILLI.—(*Baumgarten.*)

Anthrax is caused by a typical, non-motile rod, the *Bacil-*

lus anthracis. This bacillus has been carefully studied by Koch, Pasteur, and many other scientists, so that it is probably the best known of the pathogenic micro-organisms. The bacillus of anthrax multiplies by fission with great rapidity, and grows abundantly upon the ordinary culture media used in the laboratory.

FIG. 94.

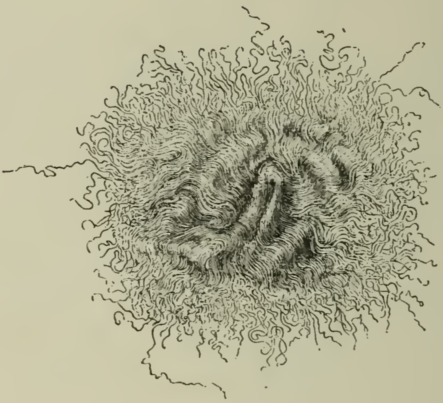


ANTHRAX BACILLI, SHOWING SPORES.

It has spores. After a few days' growth each bacillus develops within itself a highly refractive, oval body, the true endospore.

The usual method by which the infection of anthrax enters the system is through fissures, abrasions, or wounds of the skin. This is especially apt to take place upon the exposed surfaces—the hands, arms, and face—of those who work with hides and other infected objects. The infection may also be taken into the intestinal canal as a result of eating meat or drinking milk of diseased animals. Small epidemics have been described as a result of a number of persons eating the flesh of an animal that had had anthrax. The third channel through which the infection may enter the system is through the respiratory tract. This form of the disease occurs in large establishments in which wool and hair are sorted and cleaned, and is therefore called wool-sorter's disease.

FIG. 95.



ANTHRAX COLONY.—(*Baumgarten.*)

The infection of anthrax is eliminated from the body in the pus and discharges from the vesicles, carbuncles, and broken-down tissue which are frequently found associated with the disease. In the pulmonary form the infection is eliminated from the body in the expectoration. In the intestinal variety the discharges from the bowels contain the infective principle.

The infection has been conveyed by flies, probably in the same way that these insects spread the infection of typhoid fever.

The bacillus of anthrax itself is readily destroyed, but the spores have a high degree of resistance to heat and chemical agents, so that much more powerful disinfectants are required to kill this infection than are required for the non-spore-bearing bacteria, such as diphtheria, cholera, tuberculosis, typhoid fever, plague, pneumonia, etc. The disinfection for anthrax is one of the most difficult problems with which we have to deal.

Drying has little effect upon the spores of anthrax. They have been preserved in a dry state for years without losing their vitality and virulence. A dry heat of 150° C. continued for one hour is necessary to kill them. A temperature of 140° C. cannot be trusted to kill the dry spores even after four hours' exposure.

As far as moist heat is concerned, nothing less than boiling water or steam at 100° C. can be considered trustworthy. It is true that the spores suspended in a liquid are usually killed by the boiling temperature in a few minutes, but occasionally anthrax spores are met with which show a high degree of resistance to these conditions, and it is therefore necessary to prolong the exposure to two hours in order to insure penetration.

Anthrax spores may be killed with superheated steam with certainty, and this is the most trustworthy method of dealing with the infection. An exposure of fifteen minutes to steam at 120° C. or twenty minutes to steam at 115° C. is quite sufficient.

Formaldehyd gas and sulphur dioxid are incapable of destroying the infection with certainty and are therefore totally inapplicable.

It requires one hour for a 1 : 1000 solution of bichlorid to kill anthrax spores. A 1 : 500 solution acts more quickly and should be used in dealing with this infection.

Carbolic acid cannot be depended upon to destroy the spores of anthrax, and therefore is not applicable for disinfection against this disease. Tricresol in 2 per cent. solution or lysol in 2 per cent. solution may be used.

It requires a 33 per cent. solution of formalin (containing 40 per cent. formaldehyd) to destroy anthrax spores in fifteen minutes. A 15 per cent. solution takes one hour and a half to accomplish the same result.

The strengths of the disinfecting solutions as here given are all based upon their germicidal action at ordinary temperatures. Their power is very much increased by using them hot, and it is recommended always to use these solutions at or near the boiling-point in attacking such a resistant infection as anthrax spores.

It will be found safest to burn the bandages, dressings, and other objects of little value that have become soiled with the discharges from a case of anthrax. The bedding, clothing, and other fabrics that have become contaminated must be disinfected by steam or by immersion in one of the strong hot germicidal agents, using these agents under the conditions which are known to destroy the spores.

The disinfection of cadavers or carcasses dead of anthrax is a very important and difficult matter. The infection may live for years in the soil, which becomes contaminated from the bodies of animals even when buried deeply. The worms have been known to bring the spores in their intestinal canal to the surface, thereby giving rise to fresh infection after the lapse of a long time after the infected carcass was buried.

Burning is the best method of disposing of bodies dead of anthrax. This is not always practicable in the case of large animals, such as sheep and cattle. In districts where the disease prevails isolated cemeteries have been provided in order to limit the infection to a definite area. In regions where many animals die of the disease they are sometimes treated in a bath of strong sulphuric acid, and the resulting products used commercially. In isolated cases it is sometimes possible to boil the carcass piecemeal. If the bodies are buried it is important not to bleed, open or mutilate the carcass in any way, for the reason that the spores of anthrax do not form in the body unless the bacilli have access to the oxygen of the air.

TETANUS.

Tetanus is a communicable disease prevalent in certain localities and sometimes occurring in epidemic form in institutions, camps, or among the newly born children.

The disease is characterized by cramps of the voluntary muscles, beginning with the muscles of the jaw, which gives the name of lockjaw or trismus to the affection.

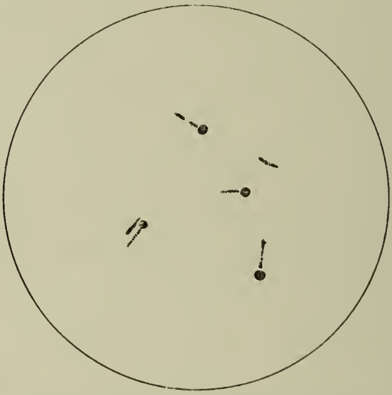
The period of incubation is usually within ten days.

Tetanus is caused by the bacillus of tetanus, first isolated by Kitasato in 1889. This organism is a slender rod, actively motile, and sometimes grows out into long filaments.

It has spores. They are small, round, glistening bodies, appearing upon one end of the bacillus, and giving it the shape of a pin. The spores become detached from the bacilli and have an independent existence, and a very high degree of resistance to heat, germicidal agents, and external influences. Under favorable conditions, such as the presence of moisture and albuminous matter and the absence of oxygen, the spores are capable of germinating into bacilli.

A peculiarity of the bacillus of tetanus is that it cannot grow and multiply in the presence of oxygen. This gas, which is so necessary to the life of almost all animals and plants, acts as a violent poison or strong germicide to the bacillus of tetanus. Even minute traces of oxygen will prevent the growth of tetanus, and in higher percentages, such as the amount of the gas as found in the atmosphere, will kill the bacillus at once. On the other hand, oxygen has no effect upon the spores of this infection.

FIG. 96.



TETANUS BACILLI, SHOWING SPORES.

The disease is always contracted through wounds, which may be of a trifling character. Deep or punctured wounds are more apt to develop tetanus because the oxygen of the air prevents the development and activity of the organism should it lodge upon the surface. There is very little reaction or inflammation set up at the seat of the inoculation. The organism germinates and multiplies locally in the wound without invading the blood or the deeper tissues.

The symptoms of the disease result from the formation of a poison called the tetanus toxin, which is soluble and is absorbed into the system and produces its baneful action upon the nervous matter. The toxin of tetanus, which is produced by the growth and multiplication of the bacillus within and without the body, is one of the most violent poisons known. An infinitesimally small amount is sufficient to kill a susceptible animal.

The infection is eliminated from the body in the pus and discharges from the wound.

The infection is kept alive and spread largely owing to the fact that many of the lower animals, particularly horses, are susceptible to the disease. The spores are taken with the hay, grass, and other food of these animals into their intestinal canals, where they germinate and multiply in great numbers, and are passed out in the manure. In this way the soil of almost all inhabited localities becomes contaminated with the infection of tetanus. The manure from horses or rich garden earth inoculated under the skin of a mouse or susceptible animal will in the great majority of cases cause the disease.

The disinfection of tetanus resolves itself into the destruction of the spores. In general the degree of resistance of these spores resembles those of anthrax very closely, and the methods of disinfection are the same.

Tetanus spores retain their vitality for months in the soil, in manure, and in putrefying materials. Drying has little effect upon them. A dry heat of 150° C. continued one hour is necessary to kill them with certainty.

They withstand a moist temperature of 80° C. for one hour, but are killed by boiling water or by steam at 100° C. in a few minutes. In actual practice it is necessary to expose objects to boiling water or to steam no less than two hours in order to insure penetration and the destruction of the spores.

Steam under pressure is the most reliable disinfecting agent we possess for this resistant infection. An exposure of fifteen minutes to steam at a temperature of 120° C., or twenty minutes to steam at a temperature of 115° C., will surely kill the spores.

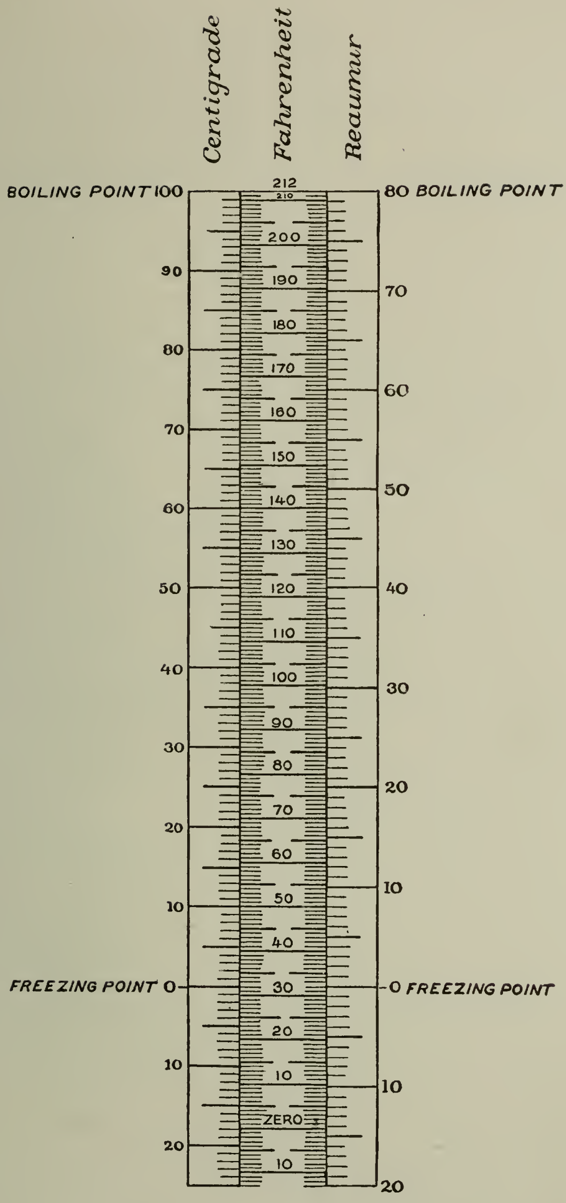
A 5 per cent. solution of carbolic acid requires fifteen hours to kill tetanus spores and is therefore inapplicable as a disinfectant for this disease. Tricresol or lysol in 2 per cent. solution may be used, with an exposure of two hours.

The spores show a high degree of resistance to a 1 : 1000 solution of bichlorid of mercury. In actual practice a 1 : 500 solution should be used.

Germicidal solutions are so much more powerful when used hot that it is strongly recommended to use them at or near the boiling-point.

Formaldehyd gas and sulphur dioxid cannot be depended upon to destroy tetanus spores and are therefore totally inapplicable as disinfectants for this disease.

APPENDIX.



Comparative Scale
OF
SWEDISH GERMAN & FRENCH
THERMOMETER

PROPORTION $9\left(\begin{smallmatrix}+32\\-32\end{smallmatrix}\right):5:4$

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SUPPLEMENT

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SUPPLEMENT

THE object of adding a supplement to Dr. Rosenau's work is to more fully describe apparatus used for disinfecting in this country the type of which has in most instances been dealt with in the body of the book. In certain instances, moreover, the methods employed differ somewhat in the two countries; especially does this seem to be the case with regard to surface disinfection of rooms. In America, preference appears to be given in practice to gaseous disinfectants, while here the application of such agents in the form of spray is receiving more approval. For some years medical officers responsible for disinfection have realized that the danger from infection in a room lies in the dust, and only so far as that dust is floating about in the air is there likely to be danger from the air itself. This view, enunciated by Dr. J. B. Russell in 1884,* has gradually led to the adoption of methods directed towards rendering such dust harmless and effecting its removal. Dr. Russell laid it down as an axiom which should guide everyone who had to deal with infectious cases that the quickest way to render temporarily innocuous infective dust was to turn it into mud, or, if moist to begin with, to take steps to keep it in that condition. In fact, he went so far as to say "that in dealing with infected liquids and with substances which are moist or can be moistened, we simply waste time in attempts to disinfect, which are not only unnecessary, but will in all probability prove futile."

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* "Glasgow Medical Journal," 1884, and "Journal of State Medicine," vol. iv., p. 407, 1896.

The recognition of the fact that infection is to be found in the dust has led in the construction of our hospitals to the adoption of smooth polished walls and floors and rounded corners ; in the treatment of pulmonary tuberculosis to the use of spittoons containing some fluid, and the damp cleansing of rooms occupied by patients ; and in our streets to better methods of cleansing by flushing, to more frequent watering, and even in some instances to a stream of water being made to run along the channel during hot and dusty weather.

It has further led to an alteration in the way in which we measure the necessary quantity of the agent—whether it be gaseous or fluid—necessary for the disinfection of a room. Formerly cubic space was regarded as the guide, but now it is rather the area of the various surfaces which determines the quantity of disinfectant which is to be used. At the same time the fact must not be lost sight of that when spray is used it also washes the air of rooms, and thus carries down organisms which may be floating therein.

Dr. Leslie MacKenzie, treating upon the question* of disinfection, remarked that if we could safely blow infected dust from floors and walls of ceilings we should not need to discuss the subject further. Unsuccessful attempts have been made to deal with the dust of rooms in this way, but lately there has been introduced a process intended primarily for cleansing carpets and the furniture of rooms ; this is satisfactorily effected by sucking out the dust by means of a vacuum. The importance of this method for the effective removal of dust from carpets, upholstered furniture, railway carriages, and such like, difficult to disinfect in a satisfactory manner, justifies a description of it here, as, without doubt, it is a valuable adjunct to our armamentarium, and its use may in great measure modify the procedure we may otherwise deem necessary in carrying out processes of disinfection and cleansing.

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* "Public Health," vol. xii., p. 593, 1900.

The Vacuum Cleaner (Booth's System).

The method is extremely simple. A high vacuum is established by means of an air-pump driven by a small motor and operated in a portable truck, which carries the entire plant. The suction of air created by this means is carried to the carpet or furniture to be treated through flexible indiarubber tubes, fitted with metal nozzles of various shapes suitable for passing over the surfaces of the objects. By this means dust contained in and under carpets is drawn up and removed along the tube to a filter attached to the truck, where the dust is collected and deposited outside the building. The operation is quick and quiet, and no dust is driven into the air. Not only may upholstered furniture and carpets be entirely freed from dust in this way, but so also may mattresses and bedding and the most delicate of fabrics. For hotels and business establishments and large houses a stationary plant

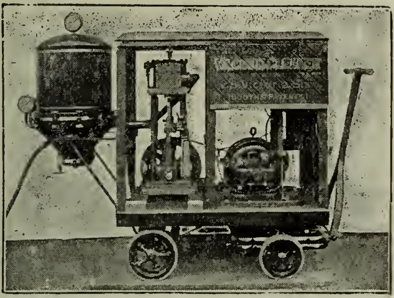

Fig. 1.—View of One of the Electric-driven Portable Plants.

Dimensions: 3 feet 6 inches long, 4 feet high, and 2 feet 8 inches wide; suitable for being moved about in lifts from floor to floor. Weight, 9 cwts.

may be installed in the basement, and a small wrought-iron pipe carried to fixed points on each floor. At these points flexible hose is attached when the plant is to be put in operation. For cleaning railway stock, tramway cars, and public vehicles, the plant may be fixed in the cleaning sheds or at the depots. There is no doubt as to the absolute success of the method.

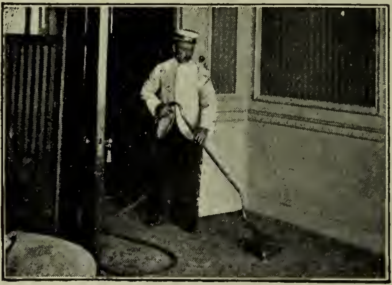

Fig. 2.—View showing Operator at Work.

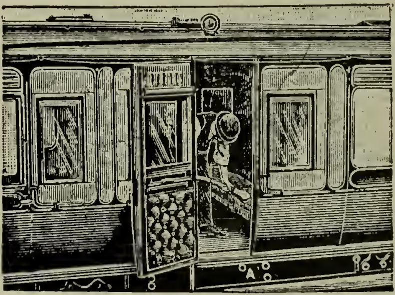

Fig. 3.—View showing Operator at work in Railway Carriage.

STEAM DISINFECTING APPARATUS.

Up to the publication of Dr. H. Franklin Parsons' report* on disinfection in 1885, dry heat was largely used in this country; but as a result thereof and of the experiments conducted by Koch and Wolffhugel,* its use became restricted to certain articles which are liable to be damaged by moist heat, and various appliances have been invented whereby articles to be disinfected can be subjected to the action of steam. Parsons stated that "the most important requisites for a good apparatus for disinfection by heat are (*a*) that the temperature in the interior shall be uniformly distributed; (*b*) that it shall be capable of being maintained constant for the time during which the operation extends; and (*c*) that there shall be some trustworthy indication as to the actual temperature of the interior at any given moment."

---

* Report of Medical Officer, Local Government Board, 1884. Appendix B., No. 10.

Steam may be employed for this purpose, either *superheated* or *saturated*. Steam at any pressure is "saturated" when it is at the boiling-point of water for that pressure. Under ordinary atmospheric pressure water becomes steam at a temperature of 212° F. (100° C.); an increased pressure of 10 lb. raises the boiling-point to 240° F. (115·5° C.), but in both these instances the steam produced is *saturated*, and any reduction of the temperature causes a deposition of moisture on objects with which it comes in contact. If, however, at any of these pressures the steam is further heated without altering the pressure, then it is known as *superheated*. It should be clearly understood that steam can be superheated without being under extra pressure, and steam can be under pressure without being superheated.

The use of superheated steam was originally introduced in order to assist the drying of objects, but it is evident that, unless a certain amount of cooling takes place when superheated steam comes in contact with the objects to be disinfected, no moisture will be deposited, and thus its efficiency may be little more than that of hot air. In practice, however, some conversion of superheated steam into saturated occurs, and in great measure it is upon this that the efficiency of superheated steam depends; the remainder of the action is done by simple conduction, which, with steam as a gas, is slower in its heating effect and less uniform than hot air (Esmarch). Hence superheated steam is more expensive in use than saturated steam, both as regards the cost of the apparatus and subsequently in carrying out the process.

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* "Mittheilungen aus dem Kaiserlichen Gesundheitsamte," Berlin, 1881.

Steam may be employed either in a *confined* form—*i.e.*, in a closed chamber from which the air has been exhausted—or drawn through the chamber in a *current*. In the confined form it is used under pressure of from 10 to 20 lb. per square inch, so that a temperature of 240° F. (115° C.) to 260° F. (126·5° C.) is maintained in the interior of the apparatus. At a low pressure, such as one of 1½ to 2 lb., a temperature cannot be obtained which can be relied upon in a closed apparatus, as the penetrating power of the steam is too feeble to drive out the air from the interior of articles under treatment. The temperature also being but slightly above 100° C., there is always a risk that it may fall below that mark. In the current form, steam is used under extra pressure, or the boiling-point of the water is raised by the addition to it of various chemicals.

Several forms of steam apparatus are in use in this country, depending upon one or other of the methods above described, such as the Washington-Lyons and the Nottingham (high pressure), the Equifex (saturated steam), the Thresh, the Delépine, and the Reck (current steam).

The Washington-Lyons Steam Disinfector.

This apparatus consists of an oval chamber with double walls forming a "jacket" round the chamber. The object of the jacket (see p. 57) is to superheat the steam, to prevent loss of heat, and, after the operation of disinfecting is finished, to dry off any dampness which may remain in the articles enclosed. Air is removed from the central part of the machine and from the interstices of the goods by means of a vacuum-producing apparatus before the process is begun, the result being that when hot air or steam is admitted the goods are more readily penetrated ; and on the completion of disinfection the steam is exhausted in a similar manner (see remarks below on the evacuation of air). Steam may be taken from an existing boiler, or may be raised specially in a small boiler put in for the purpose. This machine is usually employed at a high pressure (20 lb.), but it can be used at a low pressure, as a high or low pressure current machine, or as a dry heat oven with or without formaldehyde.

The Nottingham Steam Disinfecting Apparatus.

This is also a high-pressure apparatus, but it is constructed in rectangular form similar to that shown in Plate 19, facing p. 62, and is shown in section below.

The apparatus consists of a steel boiler, enclosing the closet, open at each end. The ends are closed by two hollow steel doors, connected to the boiler in such a manner by the pipes that water and steam are always circulating through them; consequently the inside closet is surrounded by the inner skin or plates of the boiler, which keeps the sides at an equal temperature with that of the steam. Thus there is absolutely no possibility of any condensation taking place. There is also a chamber built in the flues for heating the air, connected to the disinfecting closet by a pipe and valve. The apparatus is supplied with an exhauster, connected to the closet by the pipe and valve. Upon opening the valve and starting the exhauster, a strong current of hot air passes through the closet, and coming into contact with the articles inside, prepares them for the admission of steam. The articles are disinfected under a pressure of 20 lb. The advantages claimed for this machine are that the rectangular shape is more convenient than the ovoid ; that the apparatus is self-contained ; that no separate boiler is required, thereby effecting an economy in working, as with a separate boiler there are a double set of fittings to be looked after ; and that a loss of heat in conveying the steam from the boiler to the apparatus is prevented. It may be used with dry heat or with steam.

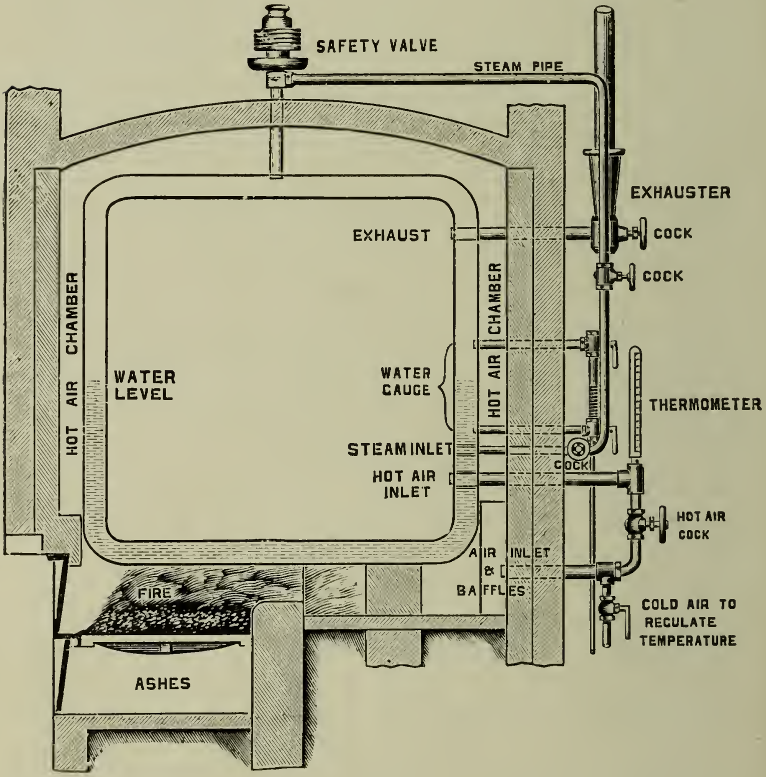

Fig. 4.—SECTION OF THE NOTTINGHAM DISINFECTING APPARATUS, SHOWING ARRANGEMENT OF STEAM AND HOT-AIR CHAMBERS, VALVES, ETC.

The Equifex Disinfector.

The Equifex disinfector, which works with purely saturated steam under pressure, consists of a chamber surrounded by insulating material, and furnished at top and bottom with coils for warming the air when it is necessary to dry. The steam that is admitted is allowed to expel the whole of the air, escaping after it through an exhaust-pipe connecting the

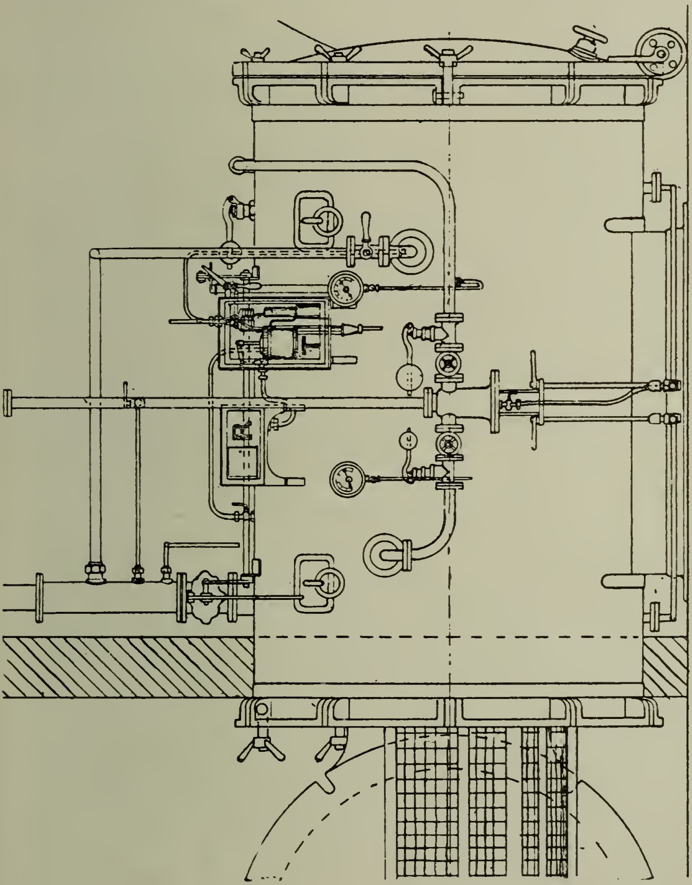

Fig. 5.—EQUIFEX SATURATED STEAM DISINFECTOR, WITH RECORDING GAUGE AND STEAM TESTER.

R, Recording gauge T, steam tester.

bottom of the disinfector with the chimney. So soon as the air is expelled the steam outlet is closed, and at the end of five minutes a large outlet closed by a sluice-valve is suddenly opened, so permitting the escape of the bulk of the steam in the disinfector and of the air which may have been occluded in the pores of mattresses, etc. This latter operation is facilitated by the sudden re-evaporation of the steam condensed in the pores under a pressure of 10 lb., when the disinfector is suddenly opened to atmospheric pressure. Just before the pressure falls to zero the sluice-valve is again closed, and the disinfection resumed for two more periods of five minutes, which may be increased in the case of specially thick objects. At the end of the operation the sluice-valve is left open and steam is admitted to an ejector or aspirator in the chimney, which, through an air-valve in the further door, sucks up a slow current of air, which, warmed over the coils, removes the moisture from the goods under disinfection. The operation of the disinfector is such that, although it works with saturated steam throughout, and the temperature of the steam reaches into the interior of any porous object under disinfection, the steam is only condensed on the surfaces of the pores, and is very readily removed when the operation of disinfection proper is over. Thus, for instance, a blanket which has been disinfected on being taken out and shaken vigorously and left to air for a few minutes will be found to be quite dry. A mattress of ordinary thickness would be dried in seven to eight minutes.

In order to control the temperature a pipe from the disinfector communicates with a recording pressure gauge, as in the French disinfector of Geneste-Herscher. The French arrangement (see p. 78), however, is open to the objection that the record may be made either with pure steam or with such mixture of steam and air as may happen to be present in the disinfector. This difficulty has recently been avoided by intercollating between the disinfector and the recorder an apparatus which prevents the passage of steam until it has been entirely freed from air. By this means it is impossible either for the attendant to be in doubt as to whether he has thoroughly got rid of the air, or for any neglect on his part to pass without being recorded on the card of the recorder. The cards of the recorder, which is kept locked, can be withdrawn daily by or on behalf of the superior officer, and furnish a complete control over the care with which the attendant has done his work.

The Equifex Low-pressure Disinfector.

In those cases where a community is absolutely unable to afford the expense of a disinfector capable of giving absolute disinfection, low-pressure disinfectors are the next best means at their disposal. The Equifex low-pressure disinfector works entirely with saturated steam, either confined, or, where the cost of steam is no object, as a current. It can be fitted with the air and pressure recorders in the same way as the disinfector for absolute disinfection.

Air in Steam.

The desirability of finding means for mechanically insuring the absence of air* from steam used in disinfection was first prominently brought forward by Professor Delépine. He recognised that the free escape of steam was not a reliable test, and proposed to condense a portion of the steam from the disinfecting chamber in a tube over water, so that by reading off the height to which the water rose in the tube when access of steam was stopped a measure of the proportion of residual air could be at once obtained. By other devices the gradual rise of water in the condensing tube was followed by a gradual fall of a float operating a recording lever, or by a series of vibrations which empirically were found to assume characteristic forms according to the presence or absence of air. This apparatus, from technical reasons, has not been adopted in practice, but recently the Equifex machine has been fitted with an apparatus which, in the manner proposed by Delépine, indicates the evacuation of air ; the appliance operates by condensing steam from the chamber, but it is so arranged that the operating gear is not affected until the whole of the air is evacuated, and no record is made on the recording gauge until this point is reached. This result is attained by introducing the steam into a siphon, of which the legs dip into separate vessels, the lower vessel being furnished with a siphon overflow. The heights are so proportioned that, until the steam siphon flushes, the lower vessel cannot be emptied, and the head in it balances off the head in the upper vessel through its pressure on the residual air in the steam siphon. So soon, however, as the last trace of residual air has disappeared, the steam siphon flushes, causing the siphon overflow of the lower vessel also to flush, and a float in the upper vessel falls as the siphon empties the vessel, and on its fall opens a valve which permits the passage of steam to the recording gauge. To keep the water cold enough for the purpose of condensation the operation of admitting steam to the siphon for trial also admits a stream of water to the vessel. The next step in the operation of disinfection being the opening of the sluice-valve to permit the escape of steam, the handle of this valve is linked to the mechanism which indicates the absence of air, in such a way that when the sluice-valve is opened water is again admitted to the upper vessel, and the passage of steam to the recorder is closed through the consequent rising of the float in that vessel.

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* It should be noted that the pressure gauge is an index of temperature only with saturated steam and in the absence of air, for with hot air or superheated steam Regnault's law does not apply.

Current Steam Machines.

Apparatus for employing current or streaming steam are described on pp. 53 and 54, but it is evident that the apparatus

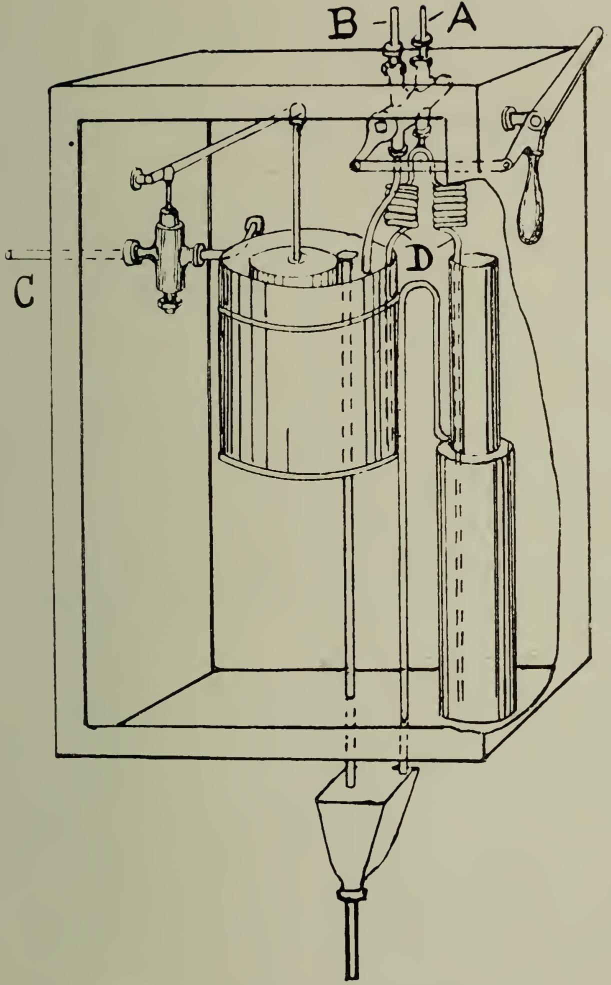

Fig. 6.—Equifex Steam Tester (shown at T on *Fig. 5*)

A, Steam inlet; B, water inlet; C, steam to recorder; D, condensing siphon.

mentioned therein do not give a temperature higher than 100° C., whereas in this country there are two machines for using steam in this form which give much higher temperatures.

The experiments of Esmarch, Delépine,* and others (pp. 46 and 47) have shown that a temperature of 100° C., if maintained for a sufficiently long period, is satisfactory for the destruction of non-spore-bearing organisms; but the difficulty has been to maintain that temperature. Besides, a longer exposure to it is necessary than with steam at a higher temperature.

Koch's experiments, made with the autoclave (see p. 56) in 1880, and published in 1881, were repeated by Heydenreich in 1883. Koch concluded that current saturated steam without pressure was an efficient disinfectant, but Heydenreich demonstrated that this result could only be attained when air was allowed to remain in the autoclave. So soon as all the air was exhausted before the disinfection began, it was observed that the rate of disinfection increased as the pressure rose.

The Thresh Disinfecting Apparatus.

In this apparatus the difficulty of maintaining the temperature in a current steam apparatus is obviated by taking advantage of the fact that when water contains a substance in solution its boiling-point is raised proportionately to the amount of the substance dissolved, and therefore the temperature of the steam given off by such a solution when boiled is several degrees higher than that evolved from water only, at the ordinary atmospheric pressure. Chloride of calcium was recommended for this purpose so long ago as 1883, but the solution was found to be destructive to the boiler, to cause “ priming ” (carrying over drops of salt solution), and consequent permanent dampness in the articles in the apparatus. Dr. Thresh found that the temperature could be raised equally well by the use of another salt—viz., carbonate of potash (K_2CO_3), and by making the boiler serve as a jacket for the disinfecting oven. The salt is added to the water in the boiler in definite proportion, and the experience of five years has proved that the boilers keep clean, are perfectly free from scale or erosion, and there is no action whatever on the boiler-plates.

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* "Journal of State Medicine," April, 1900.

Figs. 7 and *8* show the apparatus to consist of a horizontal boiler, egg-shaped in section, heated by a subjacent furnace. The steam given off is directed either to the chamber or into the chimney by a valve controlled by means of a wheel placed on the top of the front of the machine. The steam enters the chamber at the bottom and is distributed by a plate, and passes upwards to the chimney through a pipe. After the disinfecting process is complete the current of steam is diverted into the chimney and air is aspirated into the interior of the apparatus by opening the valve of a pipe (*f*), placed just beneath the door of the oven. The air so admitted passes through a coil of tubes (*e*) and is immersed in the boiling saline solution, and is thereby heated and speedily dries the articles contained in the oven. As the water evaporates from the boiler an equivalent supply is introduced automatically from a small cistern with a ball-valve.

The machines are made in various sizes, and either fixed or portable. They can be heated by a fire beneath them, in which case a simple and inexpensive brickwork setting is necessary, no separate steam boiler being required, as in most disinfectors.

Where, however, a steam boiler already exists for other purposes, the steam from same can be utilized as the heating medium. This is done by passing the pressure steam from the boiler through a coil fitted in the jacket, in which is the solution to be heated. The disinfector in such case is fixed on iron stands, and the brickwork setting dispensed with.

It will be seen at once that this arrangement will be found

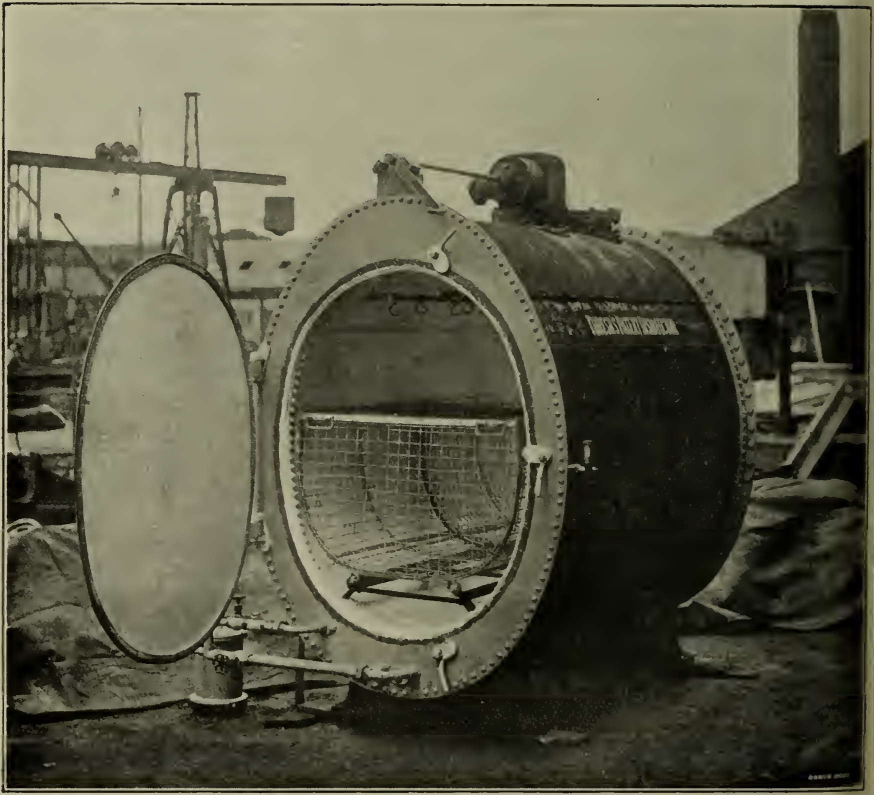

Fig. 7.—Thresh's Current-Steam Disinfector (steam-heated), showing Interior of Machine.

very convenient in large establishments where steam boilers are in use for other purposes, and that the cost of working the disinfector is practically nil.

Even where the machine is heated by a furnace the working expenses are very light.

For isolation hospitals, etc., machines with door at each end are recommended, the infected articles being put into the disinfector at one end, and removed after disinfection at the other.

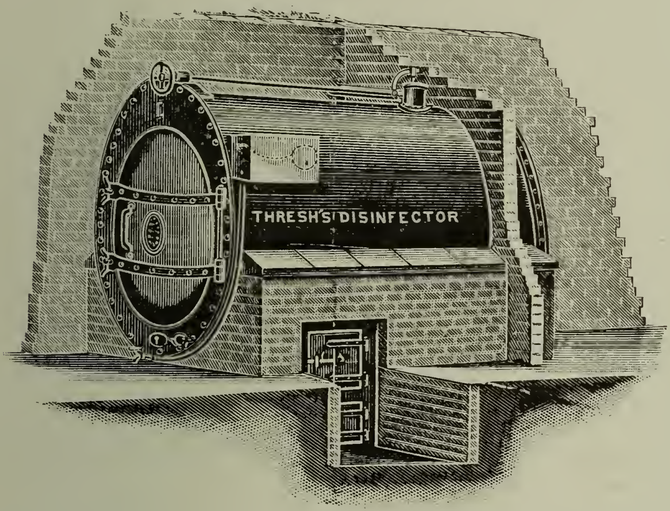

Fig. 8.—THRESH'S DISINFECTOR (FURNACE-HEATED) IN BRICKWORK SETTING.

Size.	Size of Inner Chamber.		
	Length.	Height.	Width.
A. Door at *one end* only of Disinfector	3 ft. 9 in. ×	3 ft. 9 in. ×	3 ft. 0 in.
B. ,, ,, ,, -	5 ft. 0 in. ×	3 ft. 9 in. ×	3 ft. 0 in.
H. Door at *each end* of Disinfector -	5 ft. 0 in. ×	3 ft. 9 in. ×	3 ft. 0 in.
J. ,, ,, ,, -	6 ft. 0 in. ×	3 ft. 9 in. ×	3 ft. 0 in.
C. ,, ,, ,, -	7 ft. 0 in. ×	4 ft. 6 in. ×	3 ft. 6 in.
D. ,, ,, ,, -	8 ft. 0 in. ×	4 ft. 6 in. ×	3 ft. 6 in.

For workhouses, where the disinfection of the clothing of tramps is the chief use, the need for double-door machines is not so great.

The experiments of Mearns Fraser,* Barwise,† and the "Lancet" special commission‡ show that in four minutes after beginning operations a temperature of 100° C. was obtained uniformly throughout, and that within ten minutes more this temperature was registered within sixteen folds of blankets. From these experiments it is obvious that if the articles to be disinfected are left in the apparatus for half an hour they will be at a temperature of 100° C. for more than fifteen minutes, and that for a greater part of that time the temperature will be some (2° to 4°) degrees above 100° C.

Experiments made to test the effect of the drying process showed that there was no gain in weight, and that generally articles came out of the apparatus drier than when they went in.

The conclusions of the "Lancet" commission were that the apparatus is of moderate cost, the expense of working is small, it requires no special management, and yet is free from the risks attending the use of steam under pressure. It is efficient as a sterilizer, destroying even the resistant spores of *Bacillus anthracis*, without injury to the articles and fabrics which commonly require disinfecting.

Since these reports were issued the machines have been subjected to severe tests previous to their adoption by the British military authorities.

The Delépine Disinfector.

A large number of experiments made by Professor Delépine§ showed that complete disinfection can be obtained in a very short time by the use of a rapid current of saturated steam at a low pressure. He found that steam under these conditions displaces air from the steam chamber itself, and from

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* "A New Method of Disinfection by Current Steam," "Journal of State Medicine," January, 1896.

† "Disinfection by Steam," "Public Health," vol. viii., March, 1896.

‡ The "Lancet," January 11, 1896.

§ "Journal of State Medicine," April, 1900.

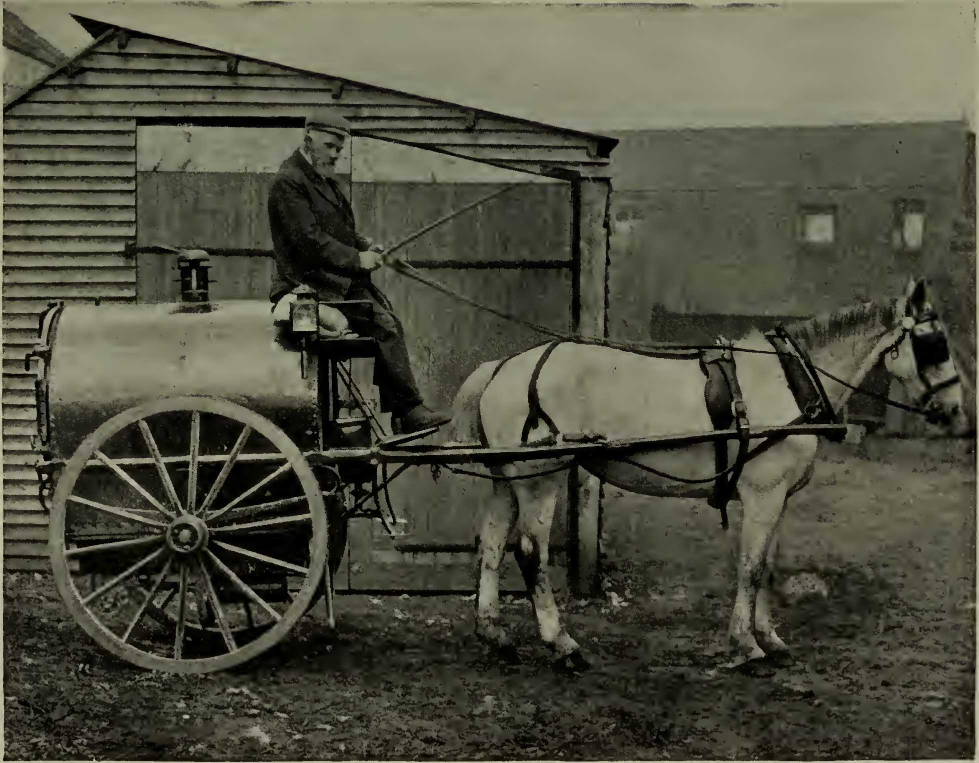

Fig. 9.—The Delépine Disinfector.

bulky objects (mattresses, pillows, etc.) placed therein, in a remarkably short time. Spores of the *Bacillus anthracis* (even when protected by sixteen layers of blankets, or the whole thickness of a mattress) are destroyed in less than one minute after the air has been displaced by saturated steam at low pressure.

The arrangement for drying articles immediately after they have been disinfected (as devised by Dr. Thresh) is applied to this machine. A continuous current of hot air is passed through the disinfector, whereby the steam retained in the disinfected articles is driven off before the apparatus is allowed to cool. This allows bulky articles to be dried sufficiently in less than half an hour after the completion of disinfection.

The weight of the machine has been kept down to a minimum campatible with strength and rigidity of its various parts. This renders the disinfector very portable.

The reduction in weight of the machine enables one to obtain quickly the necessary temperature, thereby cheapening the cost of working. In order also to obtain a rapid generation of steam, the smallest amount of water compatible with safety is used. The heat is obtained from a powerful petroleum furnace in the case of *portable* machines ; in *fixed* machines either a petroleum furnace or Bunsen gas-burners may be used. In size A. 4 feet long by 3 feet 6 inches in diameter, it requires less than 4 pints of petroleum to heat the machine, disinfect and dry one charge of bedding, at a cost of about fourpence.

The time occupied for the whole operation does not exceed sixty minutes ; in the case of light articles (blankets, sheets, clothing, etc.) it is less.

The disinfector is worked at low pressure, which is regulated by one simple dead-weight valve guarding the large steam outlet, and there is no danger of an excessive pressure being reached accidentally.

The Reck Disinfector.

This consists of a steel cylinder, oval or rectangular in shape, sufficient to give from 23 to 235 cubic feet capacity.

By all forms of this disinfector current steam is employed, and the apparatus can be had for steam pressures from 1½ ℔. (216° F.) to 7 ℔. (230° F.). The apparatus is fitted with a pressure regulator that controls the pressure (and temperature) in the chamber. A perforated valve in the outlet from the chamber allows always a certain amount of steam to escape, and the advantage of current steam is thus obtained.

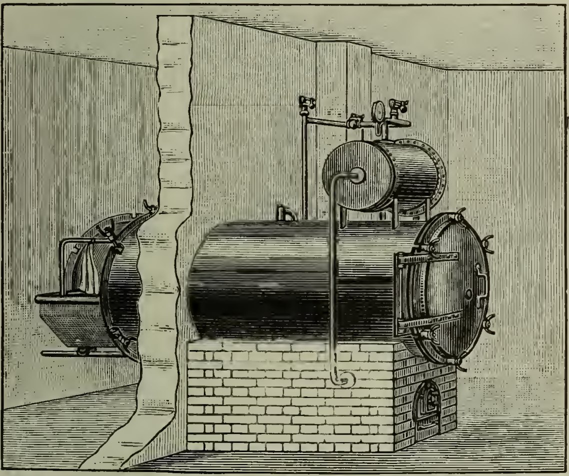

Fig. 10.—The Reck Disinfector.

The Reck disinfector was originally only made in one form. Steam was condensed at the end of the disinfection process by the sudden discharge of a shower of cold water from the upper part of the apparatus ; the water was deflected from the articles in the chamber by a protecting oval plate ; removal of condensed steam in the disinfected articles was effected in a separate drying closet heated by exhaust steam by means of radiators.

Now the apparatus can also be had for drying the articles completely inside the chamber. In this form the greater part of the chamber is surrounded by a water-jacket storing sufficient heat to dry the articles inside the apparatus, after the disinfecting process proper is finished. At the same time the water-spray is dispensed with.

Dr. Thoinot of Paris has given the results of the investigations of a commission appointed by the Directors de l'Assistance publique to inquire into the working of various disinfecting apparatus. With Reck's apparatus they found that all the articles experimented with reached 222° F., the temperature decided upon in a very short time, and that this temperature was maintained throughout the whole operation. They found that the disinfecting power was sure and equal, and that even after repeated consecutive (thirty times)

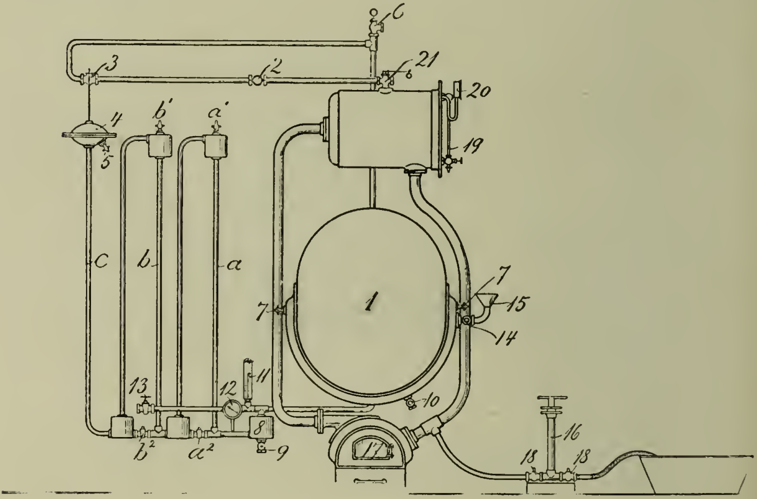

Fig. 11.—The Reck Disinfector with Water-jacket.

1, Disinfector; 2, steam valve; 3, reducing valve; 4, bowl; 5, air-cock; 6, safety valve; 7, air-cocks; 8, water-tank; 9, tap-cock; 10, tap-cock; 11, thermometer; 12, manometer; 13, perforated valve; 14, stop-cock; 15, funnel; 16, pump; 17, boiler; 18, check-valves; 19, water gauge on boiler; 20, manometer on boiler; 21, safety valve; a^1, a^2, b^1, b^2, cocks; *a*, *b*, *c*, water-columns.

disinfections very little, if any, damage was caused to the articles, in both of which respects Reck's apparatus surpassed other disinfectors then used in French hospitals.

Portable Steam Disinfectors.

All the types of apparatus mentioned may be obtained in portable form, but the following apparatus is specially made in this form. It is named " Thresh's Emergency Disinfector."

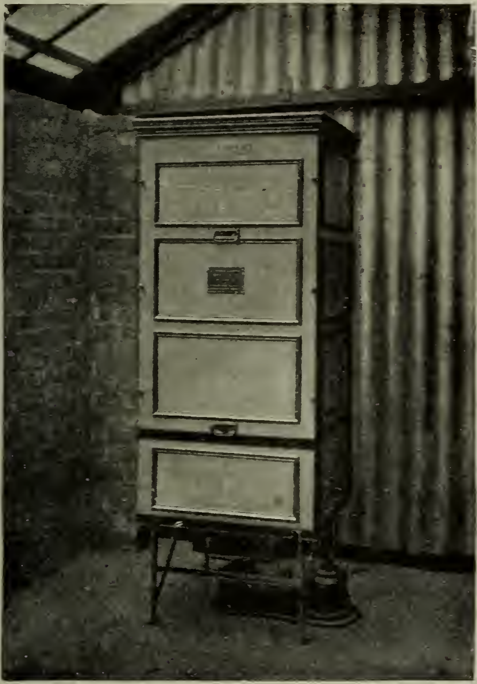

Fig. 12.—Thresh's Emergency Disinfector.

The disinfector consists of a disinfecting chamber, beneath which is a water reservoir, in which the steam is generated, mounted on an iron stand, the source of heat being a petrol furnace (*Fig. 12*). The disinfecting chamber proper consists of a light framework supporting walls of thin metal lined inside and out with non-conducting materials. The chamber is 5 feet 6 inches high and 2 feet 3 inches square, has a false bottom, and at the top a series of bars from which light articles can be suspended, and weighs 150 ℔. One side is removable and acts as a door, weighing 33 ℔. (*Fig. 13*), and is secured when the chamber is in use by six thumb-screws; at its upper part is an adjustable ventilating grating, which allows egress to the steam. The bottom of the chamber is of steel plate covered with asbestos, and having a ring of perforations near the centre. Under this plate slides an iron vessel, weighing 10 ℔., capable of holding about three gallons of water, which can be heated by a small oil furnace of great intensity. The whole

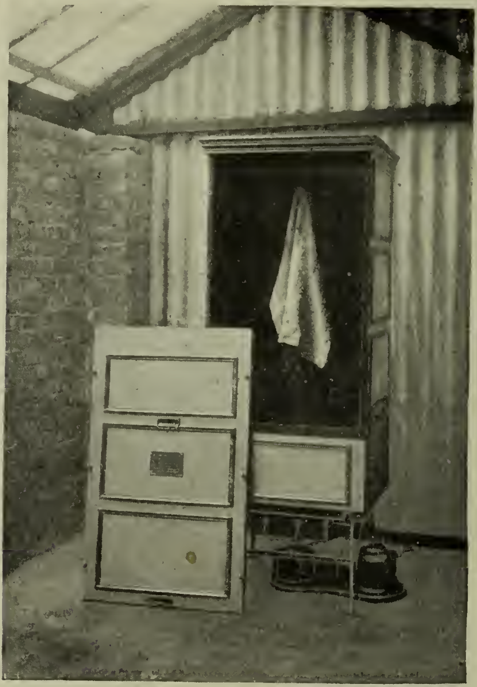

Fig. 13.—THRESH'S EMERGENCY DISINFECTOR.

is placed on a wrought-iron support, weighing 36 ℔., leaving just sufficient room for the furnace to go under the boiler. The total weight is 229℔. = 2 cwt. 5 ℔.

The machine can be used in the back-yard of any cottage, and can be carried about on a hand-cart, large handles fixed to the lower part of the disinfecting chamber facilitating its removal. The lamp-stand, boiler, etc., all pack inside the disinfecting chamber when not in use.

To use the machine, the bedding, clothing, etc., are suspended in the disinfecting chamber from the bars at the top, the door is securely fastened by means of the thumb-screws, and the ventilating grating opened. One and a half gallons of water, to which has been added 8 oz. of formaldehyde solution, are poured into the boiler, which is then placed in position, and the petrol furnace started. In about ten minutes the water boils vigorously, and steam appears at the exit grating, which is then half closed.

The temperature inside the machine is fairly uniform, and reaches 99·4° C. to 100° C. from ten to twenty minutes after steam is first seen. The steaming process continues for forty-five minutes, reckoned from the first appearance of steam at the exit, when the boiler containing the water and formaldehyde is removed, and a baffle-plate inserted in its place. This permits of very hot air entering through the perforated bottom, and in a few minutes the steam is removed from the machine. If only light goods are being disinfected, a quarter of an hour's drying is sufficient, but in the case of a bed or other bulky article at least half an hour should be allowed.

For leather goods and all materials which cannot be disinfected with steam, the machine can be used for dry disinfection by placing paraformol on the baffle-plate under the bottom of the machine, and starting the furnace, when the formaldehyde formed during volatilization passes with the heated air into the machine. The sliding ventilating grating enables the temperature to be sufficiently well regulated and maintained for any length of time.

Bacteriological tests* applied to this apparatus show its efficacy as a sterilizer when properly used, and the vigorous action of formaldehyde when carried through the disinfecting chamber by means of current steam. Exposure to current steam alone or in conjunction with formaldehyde vapour for thirty minutes was not found sufficiently reliable (although non-sporing organisms rolled in six folds of blankets were killed), but with exposure to current steam saturated with formaldehyde for forty-five minutes even the spores of the most resistant organisms, folded in twenty folds of blankets or enclosed in the interior of a rolled flock-bed, are invariably destroyed. A little care requires to be taken to regulate the temperature because, as already pointed out, there is a tendency for the temperature to fall below 100° C. when the steam generated is from water at ordinary pressure.

The advantages of this form of portable disinfector are low initial cost, small working expenses, simplicity of construction, ease of transport and of manipulation.

In rural districts an apparatus of this description should prove valuable, as there are often no proper means for removing infected articles to the disinfecting station (if one exists), whilst the destruction of bedding and clothing by burning is an expensive alternative. The combination of formaldehyde with steam insures those conditions which are essential to obtain the best results from this gas (see p. 90).

Dry Heat.

The statement made by Rosenau (p. 38), that heat under certain circumstances may be sufficient to disinfect such articles as cannot be exposed to steam, is confirmed by

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* "British Medical Journal," June 28, 1902.

Von Schomburg,* who found that the most permanent of the non-sporing pathogenic bacteria may be destroyed by an exposure of an hour to air at 100° C. if its relative humidity be between 55 and 65 per cent. He states that this may be obtained by placing a vessel containing water, not too near the source of heat, in a chamber within which the air has a temperature of 100° C. In such an atmosphere leather articles and dyed fabrics are not affected, and do not suffer even after an exposure of from six to eight hours. Von Schomburg does not consider that this method can be satisfactorily employed in the case of spore-bearing organisms.

This modified method of applying dry heat may be found useful in treating silk dresses, fur coats, feathers, leather articles, etc. (pp. 211 and 226). Any of the apparatus described may be used in this way, but ovens for hot air are specially made.

Moisture may be introduced in the way suggested, or formalin may be sprinkled on articles not likely to be injured thereby before placing them in the oven. The Thresh emergency apparatus, or a cupboard of similar shape, and an alformant lamp may be utilized.

A warning may be given here to examine formalin tablets to see that they comply with the tests given (p. 117), as practically inert tablets are to be met with, insoluble both in water and alcohol.

The Disinfecting Station.

It is indispensable for the proper carrying out of the work that the disinfecting station be as independent and isolated as possible. The station ought to comprise two rooms completely separated from each other by a wall into which the disinfecting apparatus is built so that it communicates with both rooms. One room is reserved for infected articles,

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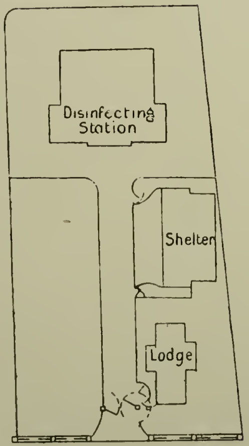
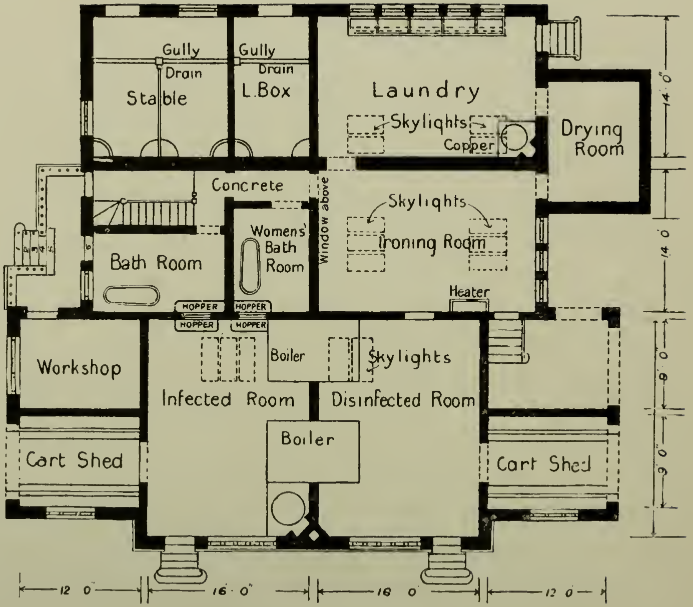
* "Zeitschrift Hygiene," 1902, 41.

HACKNEY BOROUGH COUNCIL
Plans of Disinfecting Station, SHELTER & LODGE.



PLAN OF DISINFECTING STATION.



GROUND PLAN

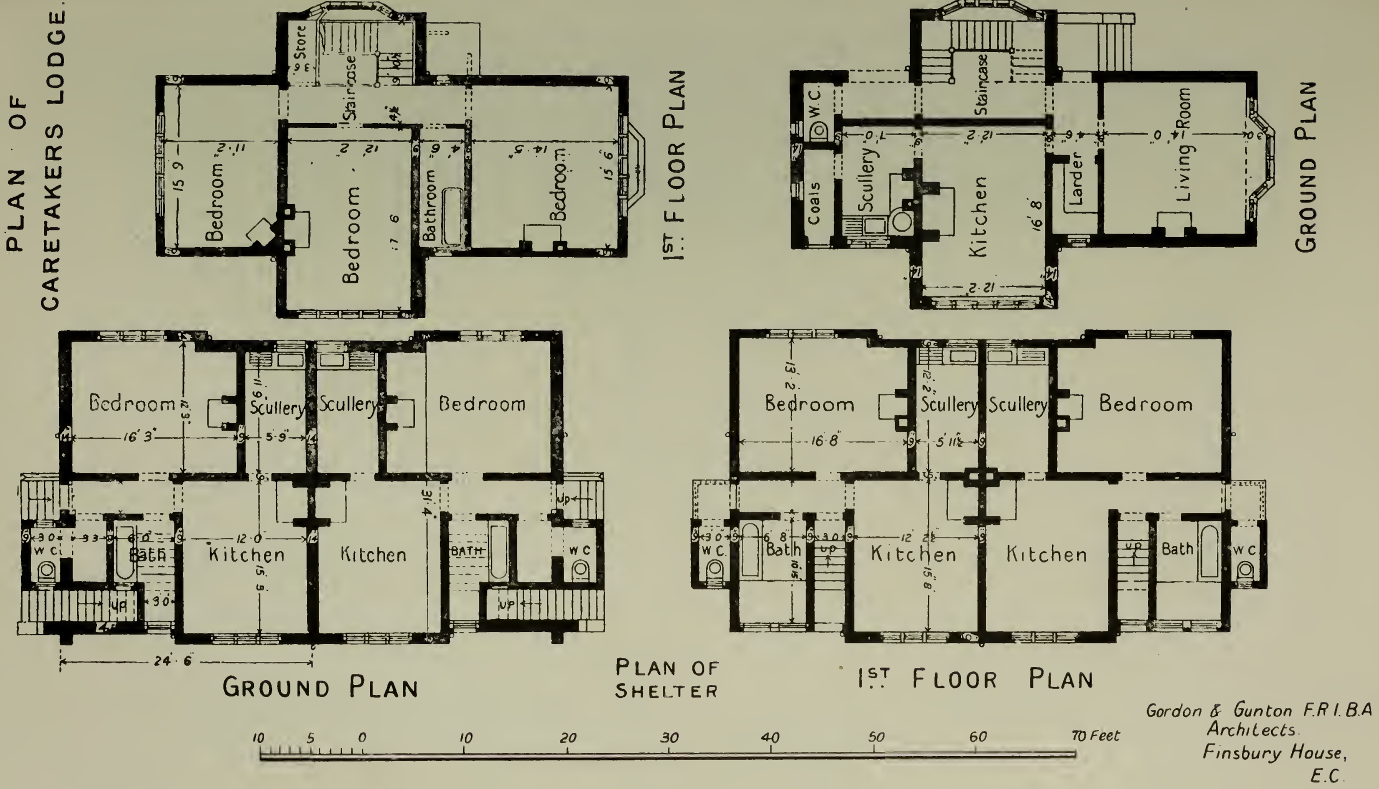

PLAN OF CARETAKERS LODGE.
1ST FLOOR PLAN
Store
Staircase
Bedroom
Bedroom
Bathroom
Bedroom
15 9
11 2
12 2
17 6
4 6
14 5
15 6
3 6
GROUND PLAN
W.C.
Coals
Scullery
Staircase
Kitchen
Larder
Living-Room
7 0
12 2
16 8
4 6
14 0
12 2
PLAN OF SHELTER
GROUND PLAN
Bedroom
Scullery
Scullery
Bedroom
Kitchen
Kitchen
Bath
BATH
W C
W C
Up
Up
16 3
12 3
11 9
5 9
12 0
15 5
31 4
24 6
3 0
9 3
6 0
1ST FLOOR PLAN
Bedroom
Scullery
Scullery
Bedroom
Kitchen
Kitchen
Bath
Bath
W C
W C
Up
Up
13 2
16 8
12 2
5 11½
12 2
15 8
6 8
3 0
10 15
10
5
0
10
20
30
40
50
60
70 Feet
Gordon & Gunton F.R.I.B.A
Architects.
Finsbury House,
E.C.

Fig. 14.

the other for those which have been purified. There should be no direct means of communication between the two rooms. Both should be well lighted, the floors and walls should be smooth and impervious, so that they may be readily washed. Water should be laid on. Racks for placing articles should be provided. A compartment for gaseous disinfection may be provided, built into the wall, so as to communicate with each room. A covered-in bath or sink is sometimes provided in which articles may be soaked in disinfectants, or even boiled. It communicates likewise with both divisions of the room.

A laundry may be provided, as shown on plan on p. *28*, of disinfecting station recently erected by Hackney Borough Council, in which linen which has been through the stove or which has been soaked in disinfectant may be dealt with.

A bathroom for the disinfecting staff, with proper places to keep their clothing, overalls, etc., should be provided.

Where provision is made for dealing with persons infected with vermin,* a separate bathroom is necessary, which may communicate by a shoot with the infectious side of the disinfecting room, so that the clothes may be passed in by the bather.

An incinerator or destructor is a useful addition for burning articles too soiled or otherwise not worth disinfecting.

Dr. Sergeant's incinerator is built in retort shape, lined with fire-brick, so constructed that the interior lining can be renewed without taking down the outer structure. The refuse to be destroyed is fed in through a hopper at the top, or, for large goods, such as mattresses, through the side ; should liquids be thrown in they collect in the bottom of the retort and gradually evaporate. There is a furnace in the front in which a coal-fire is lit in the first instance for setting fire

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* Cleansing of Persons Act, 1897.

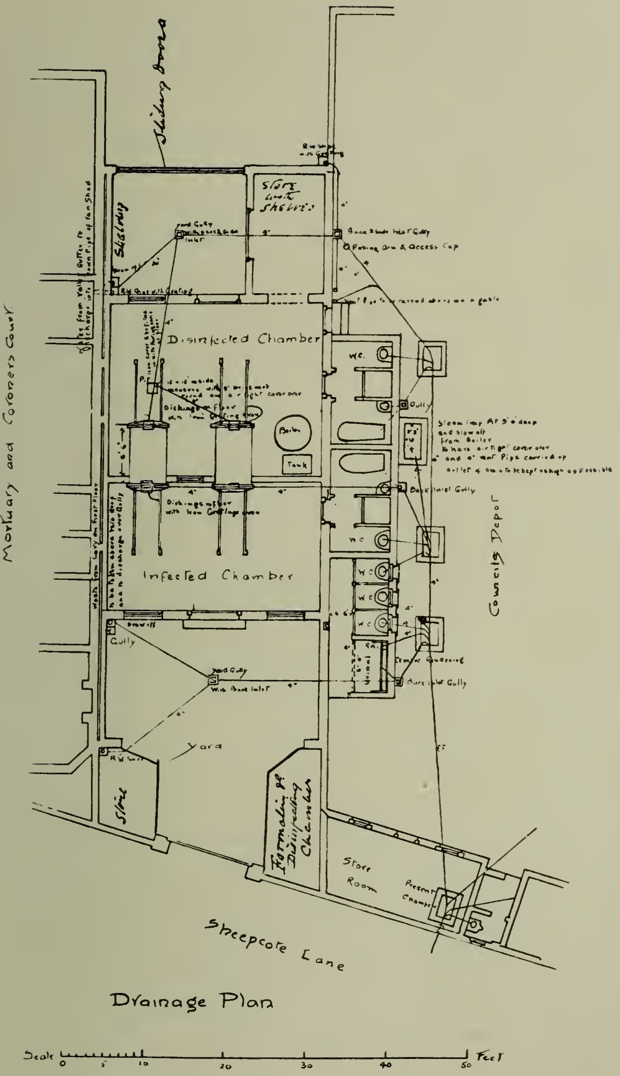

FIG. 14*a*.—PLAN OF DISINFECTING STATION ERECTED BY BATTERSEA BOROUGH COUNCIL.

to the refuse, and which can easily be dispensed with after heating has once been obtained in the retort, provided the refuse is of an inflammable nature. The gases from the furnace should always pass through a small second fire of coke in order to destroy the products of imperfect combustion. It also prevents nuisance from smell and smoke.

Two vans should be provided for the transport of articles and apparatus to and from houses. They should be painted in distinctive colours, and one should be kept entirely for infected articles, the other for conveying home the purified articles. Covered shelters for the vans are shown on the plan, as well as stables and loose-box for horses.

A store is necessary to keep the various articles necessary for disinfection of houses.

The men employed in the work should put on special suits or overalls (which can be readily disinfected), removing them before leaving the infected house. Articles to be disinfected should be placed in bags or wrapped round in waterproof sheets (wicker baskets are used in Paris for conveying delicate objects).

A list of articles removed should be made out and checked by the owner, with whom a duplicate is left. On returning the goods the owner should certify the correctness and condition.

Both Hackney and Battersea Borough Councils have constructed during the last year disinfecting stations, plans of which are reproduced here through the courtesy of their officials. The Battersea building is constructed for the accommodation of two Equifex saturated steam disinfecting apparatus, and consists of a chamber for infected goods, entered through a yard from Sheepcote Lane, and having a van shed, a bath-room, and w.c. for the attendant adjoining, and a chamber for disinfected goods. entered from Burns Road, also provided with a van shed, store-room, bath-room, and w.c. for the attendant adjoining. The chambers are lined with glazed bricks throughout, and are well lighted and ventilated by lantern lights extending the whole length. A separate chamber for chemical disinfection has also been provided.

The two disinfectors have been supplied by Messrs. Defries and Sons, and are so arranged that the goods to be treated are placed in them by the attendant in the "infected" chamber, and after treatment are removed by the attendant in the "disinfected" chamber, there being no communication between the two chambers except through the apparatus.

GASEOUS DISINFECTANTS.

Various forms of apparatus for the production of formaldehyde for room disinfection are described (pp. 87-112), and the conditions necessary to secure its successful action are set out on p. 90. The most important requirements are that the gas be evolved rapidly in sufficient quantity, and that sufficient moisture be present. H. W. Hill* corroborates this, and states that he found that an amount of gas which failed to kill in six hours at 42 per cent. humidity killed in twenty to forty minutes at 100 per cent. Generation by boiling in the ordinary way was too slow. These results support the method employed in the Thresh emergency apparatus.

S. Rideal† infers from experiments made with Thursfield's lamp that the resistant spores of anthrax may be killed when 7·5 c.c. of formalin per cubic metre (84·99 grammes of formaldehyde per 1,000 cubic feet) are vaporized with not less than four times its volume of water, and that the exposure need not exceed a period of six hours. A larger amount of the disinfectant rapidly evolved is of greater value than prolonged exposure to a less quantity of the gas.

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* Report of Committee of the American Public Health Association, "Journal of American Medical Association," January 3, 1903.

† "Journal of the Sanitary Institute," vol. xxiii., part 4, January, 1903.

It is a question on which authorities are divided whether in all cases it is necessary to use a strength of disinfectant sufficient to kill the most resistant organisms or only such a strength as will destroy the class of organism likely to be present. For practical purposes the latter view appears the correct one, a reasonable margin of safety always being allowed.

Recently Klein, A. C. Houston, and Gordon* have conducted experiments with formaldehyde and sulphur dioxide, the former being evolved from formalin tablets, the latter from burning sulphur. The organisms used were *Bacillus typhosus*, *B. diphtheriæ*, *B. pyocyaneus*, *Staphylococcus aureus*, spores of anthrax distributed in milk broth and melted gelatine, and also dried tubercular sputum. With formaldehyde (twenty-three tablets per 1,000 cubic feet) all the organisms exposed for five hours on linen were killed, and all but anthrax spores on paper. Where the tubercular sputum had penetrated into the interior of thick cloth it was not destroyed. With sulphur dioxide (3¼ ℔. per 1,000 cubic feet), after exposure for twenty-four hours, similar results were produced, save that in no instance had it destroyed the virulence of the dried tubercular sputum. No statement is made as to the presence or absence of moisture or of the temperature in the room during these experiments. They, however, corroborate a previous set of experiments made by C. H. Cribb, Geo. Newman, and F. J. Allan,† in which both temperature and humidity were noted. They used ten tablets of paraform per 1,000 cubic feet in an alformant lamp, and exposed the organisms both in a dry and moist state. These were *B. typhosus*, *B. diphtheriæ*, *Staphylococcus aureus*, and the organisms of plague and anthrax (non-spore bearing). The results were similar to those obtained by Klein. With sulphur dioxide experiments were made with a variety of strengths, beginning with 1 ℔. per 1,000 cubic feet, and going on to 2½ ℔. It was found that the diphtheria bacillus was very easily killed, an exposure of four and a half hours to the lowest strength being sufficient to destroy it, whether it was in a dry or moist state, on paper and linen. The growth of *B. typhosus* was not always prevented even with twenty-four hours' exposure to the strongest strength of the gas. *B. choleræ*, dried on paper, was killed after eight hours' exposure to the highest strength, but *B. anthracis* (spore-bearing) was unaffected.

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* Report of the Medical Officer, London County Council, 1902.

† "British Medical Journal," August 13, 1898.

Lingner's Disinfecting Apparatus.

Houston* and Newman have subsequently conducted experiments on a new form of formaldehyde generator (Lingner's)

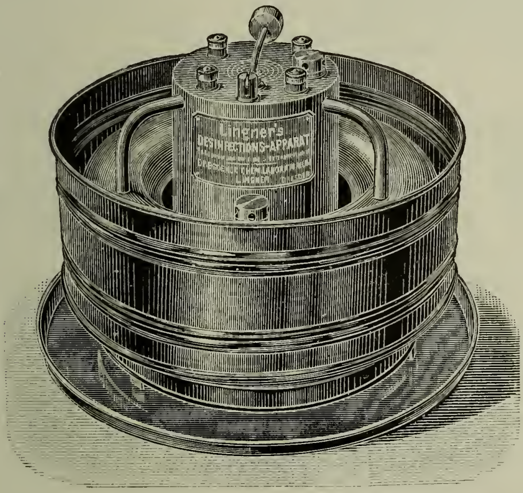

Fig. 15.—LINGNER'S DISINFECTING APPARATUS.

of which they think highly and as likely to place gaseous disinfection on a surer footing. This apparatus consists of a ring boiler (*Fig. 16, B*) in which steam is generated and driven into a reservoir (*A*) filled with formalin or glycoformol (30 per cent. formalin with 10 per cent. glycerine, see p. 105), which is thus thoroughly vaporized and ejected in the form of a fine spray through four nozzles (*d*) in different directions out of the reservoir.

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* "Practitioner," September, 1902.

The effect of the process is that in ten minutes after the apparatus has begun to work a room of 3,500 cubic feet is so densely filled with vapour that an incandescent lamp burning in the middle of the room cannot be seen. After four hours' exposure Houston and Newman found that unvarnished wood, cloth, linen, and paper soaked in strong emulsions prepared from agar cultures of *B. pyocyaneus* and *Staphylococcus aureus* and allowed to dry were entirely sterilized. In experiments carried out by Klein *B. anthracis* and virulent tubercular sputum were completely disinfected. Escherich* and others regard the Lingner apparatus as superior to any apparatus

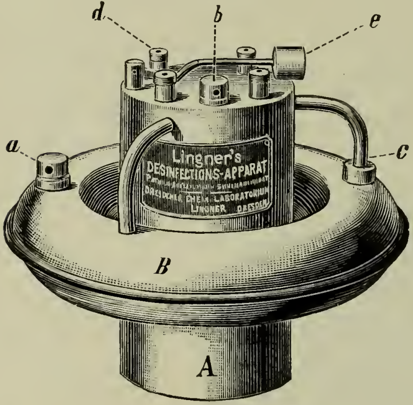

Fig. 16.
LINGNER'S DISINFECTING APPARATUS.

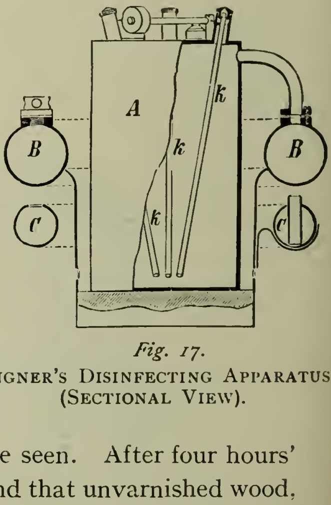

Fig. 17.
LINGNER'S DISINFECTING APPARATUS (SECTIONAL VIEW).

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* "Deutsche Med. Wochenschrift," xlvii., November 17, 1898.

hitherto used for generating this gas. It evidently generates the gas rapidly and accompanied with the high degree of humidity which is essential to successful working. Two litres of glycoformol is the amount recommended to be used for a room of 2,800 cubic feet. Leather-bound books and leather-seated chairs are said not to be injured in any way, but insects are killed. Surface disinfection appears to be thorough, and the amount of penetration shown is better than in the experiments with formalin tablets quoted above, but even with this apparatus the disinfection is still largely superficial.

The Thursfield Apparatus.

This apparatus, as described by S. Rideal,* consists of a steam generator A, containing an annular vessel for vaporizing the formaldehyde solution ; the necessary quantity of water is fed through the hole B, which also acts as a safety valve. The formalin solution is added through the chamber C, which is closed by a blast-pipe D, through which the steam and formaldehyde vapour escape. A thorough mixing of the steam and formaldehyde takes place in the chamber C, and any desired ratio of water to formalin can be employed, while the amount volatilized can further be regulated by varying the amount of spirit in the spirit-lamp F.

Two different lamps are available, one capable of vaporizing 20 c.c. of formalin and 500 c.c. of water by 120 c.c. of methylated spirit, and therefore capable of disinfecting a carriage or cab or large wardrobe. With this apparatus the formaldehyde is given off five minutes after lighting the lamp, the water boils in eight minutes, and the whole is vaporized and the spirit exhausted in about one and a half hours. The larger lamp consumes 800 c.c. of spirit, and vaporizes 3 litres of water and a maximum of 750 c.c. of formalin, being sufficient to sterilize exposed spores in a room of 100 cubic metres capacity on the assumption that 7·5 grammes of formalin per cubic metre is the active quantity required.

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* "Journal of the Sanitary Institute," vol. xxiii., part 4, January, 1903

Sulphur Dioxide.

Experiments show that for most organisms reliance may be placed in sulphur dioxide as a surface disinfectant, but to kill the more resistant organisms it should be used in not less quantity than results from burning 3 ℔. of sulphur per 1,000 cubic feet of room space, and there should be an exposure of twenty-four hours. The presence of moisture adds greatly to the efficiency (see also pp. 120-122).

The diphtheria organism was found by Allan and Newman to be readily killed even when dry, and after a much shorter exposure than twenty-four hours, so that in disinfecting rooms (from which all textile articles have been removed) after diphtheria cases an exposure of six to eight hours should be sufficient. Experience* leads to the conclusion that the same holds good for scarlet fever.

A convenient form in which to use sulphur is in the shape of candles, which can be easily lighted; they are free from danger of fire, and, being placed in water, moisture is given off at the same time. Each 1-℔. candle yields nearly 12 cubic feet of sulphur dioxide.

Spottiswoode Cameron,† while admitting that the germicidal power of SO_2 may be limited, considers that this cannot be regarded altogether as the measure of its disinfecting value. He is not prepared to say that, because the fumes of burning sulphur do not destroy anthrax spores, the process usually adopted is altogether useless. The material in which the bacterium will have to live and multiply is generally com-

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* H. Kenwood, "British Medical Journal," August 22, 1896.

† "Public Health," vol. vi., p. 214, 1894.

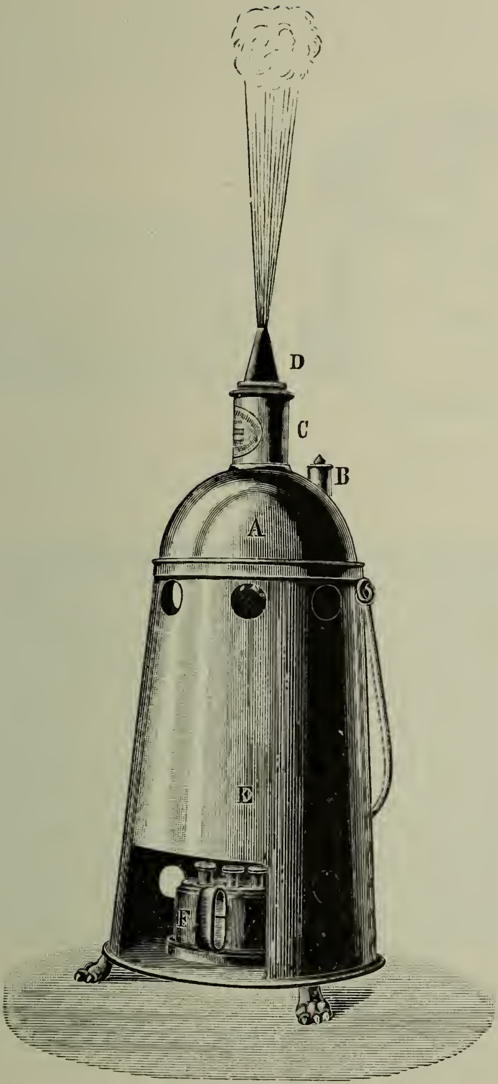

Fig. 18.—THE THURSFIELD APPARATUS.

posed of organic dirt, much of it voided in the process of respiration. The attack upon one part of this material of the sulphurous acid, in its search for further oxygen, and upon another part of the nascent oxygen set free from the water molecule, tends probably to break up these organic substances into less complex forms, and to leave a less favourable nidus for the development of pathogenic bacteria.

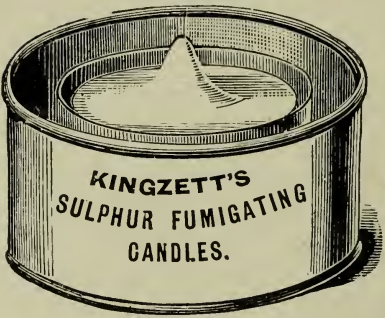

Fig. 19.
1-℔. Candle in a Double or Water-jacketed Tin.

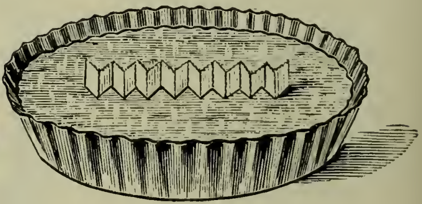

Fig. 20.
1-℔ Candle in Tin Tray, which may be stood in Water.

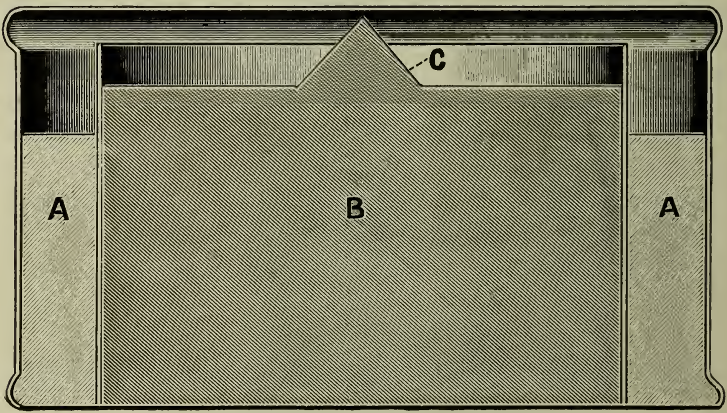

Fig. 21.—Formic Sulphugator.

A combined form of candle, known as the "formic sulphugator," generates sulphur dioxide in association with the vapours of formaldehyde and water.

Sulphur dioxide under pressure may be relied upon for the disinfection of ships infected with plague and cholera, provided the concentration of the gas reaches at least 8 per cent.*

FLUID DISINFECTANTS.

Coal-tar products form the basis of many preparations recommended by manufacturers for disinfecting purposes. The fluids commonly known as "crude carbolic," or "100 per cent. carbolic" are often specimens from which the bulk of the phenol proper has been abstracted, and consist of tar acids (cresols) and neutral tar-oils. The cresols† (see also p. 158) in a pure state are soluble in about 1 in 29 of water, but the presence of even small quantities of insoluble or only slightly soluble substances, as xylenol or thymol, diminishes considerably their solubility. Hence, in utilizing the "crude carbolic" in solution it is usual to employ solvent or emulsifying agents, and thus a number of proprietary articles have been produced under fancy names. The activity of these preparations depends upon the proportion of cresols they contain as well as the manner in which they are presented, and it sometimes happens that the fluid may consist almost entirely of inert tar-oils. A well-purified cresylic preparation should be from two to three times the strength of pure carbolic.

In ordering disinfectant fluids of this class F. W. Alexander‡ recommends that a guarantee should be obtained that they are commercially or practically free from " salting "—*i.e.*, the deposit of crude naphthaline which will occur in cool weather with a black miscible carbolic disinfecting fluid which has been manufactured during a warm period of the year, when it is difficult to properly extract the excess of naphthaline. When " salting " takes place the liquid becomes thick and will not flow out of the vessel. It is therefore necessary, in selecting one of these preparations, to ascertain these facts and their relation to price.

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* "Experiments by A. Calmette and Hautefeuille on the Clayton Apparatus," "Revue d'Hygiene et de Police Sanitaire," tome xxiv., No. 10, October, 1902.

† "Chemistry of Tar Products," by Alfred H. Allen.

‡ "Lancet," January, 1900.

Laplace found that mixtures of crude carbolic acid with an excess of concentrated sulphuric acid prepared in the cold dissolve readily in water and form a disinfectant useful against the organisms of cholera and typhoid fever.

Scheurlen and Bechman a few years ago published* the results of experiments indicating that the germicidal action of carbolic acid was increased by the addition of sodium chloride. One per cent. carbolic acid with 24 per cent. common salt gave better results than a 6 per cent. solution of carbolic in plain water. The same result was obtained with cresols. Hence it is advisable to make solutions with salt water. Scheurlen and Bechman were of opinion that the salt took up some of the water, thus making the solution of carbolic acid stronger. Römer,† of the Institute of Hygiene of the University of Monaco, repeated and confirmed these experiments, but suggested another and more feasible explanation of the action of the salt. Having in mind the fact that micro-organisms contain substances analogous to serum albumen, he made experiments on the lines of those of Bucher. If to a solution of albumen a 3 per cent. carbolic acid solution be added, no precipitate is formed, but if a 1 per cent. salt solution be also added, the albumen is thrown down. Römer concluded that through the action of the salt a chemical compound was formed, and that the germicidal action of the mixture was due to this reaction. He found that Glauber's salt and bicarbonate of soda acted in the same way as common salt.

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* "Arch. f. Experiment. Pathologie," xxvii., 1, and "Cent. f. Bakt.," xx., 16, 17.

† "Clinica Veterin.," "Journ. d'Hygiene," April, 1899.

The disinfectant value of powders made with lime is very small (Allen), the lime compounds of the cresols being practically valueless for this purpose (C. M. Tidy). The quantity of active ingredient in some powders is sometimes infinitesimal, and an examination of "carbolic" powders should be made from time to time to see that they comply with the standard which may have been laid down.

Carbolic Acid (Absolute Phenol, see p. 156).—Klein, Houston, and Gordon, experimenting with a 5 per cent. watery solution, found that after soaking cloth, linen, paper, and pieces of plain wood charged with various organisms for twenty-four hours, all the organisms except anthrax spores were destroyed. Tubercle sputum was also completely disinfected. They do not appear to have tried exposure for shorter periods with solutions of greater strength. Klein has elsewhere stated that ½ per cent. solution is capable of killing the typhoid bacillus in two hours' exposure, that a 5 per cent. solution (1 in 20) will kill the staphylococcus and the *B. coli* in five minutes.

Houston found that a strength of 1 per cent. would kill the latter organism on infected linen in one hour, and recommends when this agent is used that a strength of 1 in 50 be employed for the disinfection of linen in ordinary cases, of 1 in 25 in exceptional cases; and for disinfection of excreta the addition of one or two pints of a 1 in 4 solution, well mixed and allowed to stand at least one hour (see also p. 205).

Lysol (see p. 159).—Recent investigations on the value of lysol have been conducted by Hautefeuille,* who found it a germicide in strengths of ½ per cent. to 2 per cent. for most pathogenic organisms, killing them in a few minutes when freely exposed. A 2 per cent. spray was also successful in killing streptococci, staphylococci, *B. coli*, *B. typhosus*, *B. diphtheriæ*, and the pneumococcus exposed on paper. When these organisms were contained in pus or membrane the result was the same, but it was necessary to keep them in the solution for some time. To sterilize tuberculous sputum it is necessary to keep in contact with a 2 per cent. solution for twenty-four hours, or with a 4 per cent. solution for at least twelve hours; the solution must be well mixed with the sputum. Lysol is about two and a half times stronger than pure carbolic.

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* "Revue d'Hygiene," xxv., 2, p. 167, 1903.

Chinosol is a crystalline yellow powder with a faint aromatic odour and a peculiar astringent taste. It is a chemical compound of the quinoline group (C_9H_7N) of coal-tar products. It is readily soluble in water, forming a bright yellow solution which does not deteriorate by keeping. Chinosol does not injure or discolour the skin, and does not coagulate albumen, but it discolours articles made of iron. Experiments by Klein in 1897 show that it acts as a germicide after five minutes' exposure in a strength of 1 in 150 on *Staphylococcus pyogenes aureus*, *B. coli communis*, and in 1 in 100 strength on spores of *B. anthracis*.

Thresh and Sowden found that chinosol was a reliable disinfectant used as a spray in 1 in 100 strength; below that the results were not uniform. Houston was unable to destroy *B. coli* in excreta even with so strong a solution as 1 in 62, and considers that C. A. Hill and J. H. Abram* placed too much reliance on chinosol when they found that a 1 in 600 strength mixed with typhoid stool gave complete sterilization in half an hour. Alkaline solutions, or the presence of soap in them, interferes with its action, and it should not be used with other disinfectants, especially the mercury salts. The solution should be made in glass or china vessels.

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* "British Medical Journal," April, 1898.

Izal.—Several years ago an attempt was made to prevent a great waste occurring when coal was converted into coke in the ordinary beehive oven. It was found that a reversal of the ordinary method of burning gave a yield of gas, aqueous liquid and oil, instead of the usual waste smoke. The investigation of the nature and uses of these was undertaken by J. H. Worrall, who found that these by-products, although obtained from coal, were remarkably different from the products issuing from a gas-retort. The combustible part of the gas consisted principally of methane and hydrogen ; the aqueous liquid was noteworthy as having nearly the whole of its contained sulphur in the form of thiosulphate ; whilst the oil in its general characters was intermediate of the benzene and the paraffin series. One of the principal differences between this oil and petroleum consisted in the fact that about one-third of it was oxidized, whilst its demarcation from coal-tar was shown by the practical absence of benzene, naphthalene, anthracene, and carbolic acid, and the presence of notable quantities of solid paraffins. The oxidized part of the oil is the immediate source of izal oil. When first separated from the original crude oil the izal oil still retains a small proportion of the unoxidized oil. It is therefore, after a primary distillation, again extracted, washed, and redistilled, and appears as a reddish-brown transparent liquid, insoluble in, and of greater density than, water. It has neither an acid nor an alkaline reaction, but behaves like a body containing hydroxyl. Dilute alkalies do not dissolve it, but it is soluble in strong alkalies, as, for instance, NaHO of density 1·20, forming a clear solution. Subjected to fractionating, it was found that it differed from any recorded phenols of coal-tar, and to be more highly hydrogenized in proportion to the carbon than the recorded member of the carbolic acid series most nearly corresponding. This is shown in the following comparison of percentages yielded by izal and by the three first members of that series :

Izal.		Phenol (C_6H_6O).		Cresol (C_7H_8O).		Xylenol ($C_8H_{10}O$).
C = 75·6	...	76·6	...	77·8	...	78·7
H = 8·4	...	6·4	...	7·4	...	8·2
O = 16·0	...	17·0	...	14·8	...	13·1

Moreover, fractions having the same boiling-point as coal-tar fractions have a distinctly lower density, as shown below :

Fraction Boiling at		Density at 15·5° C.		
		Izal Oil.		Phenols.
212° to 235° C.	...	1·018	...	1·049
235° to 250° C.	...	1·024	...	1·057
250° to 300° C.	...	1·055	...	1·119

Both the density and ultimate analysis show that izal oil consists chemically of oxidized hydrocarbons, having a larger portion of hydrogen to carbon than the members of the phenol (C_6H_6O) series, and a less proportion than the members of the methyl alcohol (CH_4O) series.

The boiling-point of izal oil is over 200° C., that of the cresols ranging from about 185° to 201° C. Izal oil was found to possess considerable disinfectant powers, and the facts that it does not burn or irritate the skin, and that it is not poisonous to the higher forms of life, signal it out from most other disinfectants.

The name " izal " is ordinarily applied to the 40 per cent. emulsion of izal oil, in which form it is placed upon the market, and in further reference to izal it is the emulsion which is meant. This emulsion mixes readily with water, salt water, dilute acids, and saline liquids, without the active ingredient being in any way interfered with. It may be taken as eight times the strength of pure carbolic acid as a germicide for the typhoid fever bacillus.

Klein's experiments in 1892 proved that, diluted in the strength of 1 in 200 (about a teaspoonful to a pint), izal will kill in five minutes the organisms of cholera, diphtheria, typhoid fever, pneumonia, and non-spore bearing forms of *B. anthracis* and *B. subtilis*. For virulent anthrax spores an exposure of twenty minutes to a 10 per cent. strength is required. A. C. Houston,* from experiments conducted by him, recommends a 1 in 200 strength to be used for the ordinary disinfection of linen, and a 1 in 100 strength for exceptional cases for washing surfaces of rooms, and for mixing with excreta in cases of typhoid fever, etc. Thresh and Sowden's† experiments showed that a 1 in 100 strength used as a spray was sufficient to destroy pathogenic and other germs on wood and paper, *B. diphtheriæ*, *B. typhosus*, and *B. choleræ* being killed by half that strength, as in Klein's experiments. Although it does not stain or injure wall-paper when used as a spray, its want of volatility makes it inferior to formalin in this respect. It is better employed for washing surfaces applied either by hot or cold spray, douche, or by hand, in which circumstances the high temperature required to volatilize it is an advantage, as this, together with its insolubility in water, secures prolonged action on the surfaces with which it is brought in contact. The freedom of izal from poisonous properties renders it specially suitable for distribution by sanitary authorities.

Izal has been used with good results in the treatment of dysentery and typhoid fever,‡ in the disinfection of hands and skin,§ and for sponging the body in infectious diseases.

Creolin.—The composition of Creolin, as set forth on p. 159, is not identical in composition with that of the fluid now sold under that name in the United Kingdom and British possessions. The composition of Creolin has been modified recently with a view to obtain the highest germicidal value with the lowest possible toxicity.

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* "Practical Disinfection in Schools," "Practitioner," September, 1902.

† "Journal of the Sanitary Institute," vol. xxiii., part 4, January, 1903.

‡ "British Medical Journal," November 10, 1900.

§ W. Bruce Clarke, "Lancet," July 1, 1893.

The prospect of finding such a disinfectant was discussed by Sir Lauder Brunton as far back as 1889, in his Croonian Lecture on "The Relation between Chemical Structure and Physiological Action."

This fluid does not contain carbolic acid or any of its homologues, but relies solely for its high efficiency on certain members of another series which have been recently isolated. These new bodies are completely insoluble in water, a fact which possibly accounts for the absence of toxicity. On the other hand, when properly emulsified in the form of Creolin, they have been found to yield bacteriological results of the greatest value. For example, Klein* proved that a dilution of 1 in 400 is a complete disinfectant for *Staphylococcus pyogenes aureus* in five minutes' exposure. Tuberculous sputum containing virulent tubercle bacilli deposited and dried on wood was sterilized after soaking for twenty-four hours in all strengths up to 1 in 800. From experiments made by other observers, it has been found that Creolin is ten times stronger than pure carbolic acid as a germicide for *B. coli communis*, and twelve times stronger for *B. typhosus;* whilst its caustic properties have been demonstrated to be ten times less, and its toxic properties eight times less than carbolic acid.

Creolin is therefore a reliable disinfectant, and is safe for the public to use. As it contains no carbolic or cresylic acid, it does not come under the restriction as to sale which prohibits articles containing even 3 per cent. of these substances from being sold, except by chemists. For general use a dilution of 1 in 400 may be recommended.

Perchloride of Mercury (see pp. 152-156).—The Local Government Board (England and Wales) recommends that when this substance is used a solution should be made by dissolving ½ ounce of corrosive sublimate in 3 gallons of water to which 1 ounce of HCl has been added, and coloured with 5 grains of commercial anilin blue (if the purified article is used 1 grain is sufficient), with sulphate of copper, or other colouring matter, to prevent accidents. This gives a solution of about 1 in 960. In many instances it may be more convenient and safer to make the solution from the drug in compressed form. If the solution is to be used for spraying walls of rooms the colouring matter should not be added. For this purpose a solution of 1 in 1,000 may be made, with the addition of 3 to 5 per 1,000 of tartaric acid.

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* "British Medical Journal," January 10, 1903; "Lancet," March 21, 1903.

It must be kept in mind that, owing to the reduction and fixation of the mercury in animal and vegetable tissues, the disinfecting power is rapidly lost even in the presence of an acid. Sclavo and Manuelli* found that of textile fabrics silk and wool are most active in effecting the reduction, cotton and linen less so. Thus, after soaking 10 grammes of wool in 100 grammes of a 5 in 1,000 solution for half an hour, and then wringing out, the amount of metallic salt in the fluid was inappreciable. The presence of hydrochloric acid only slightly retarded the loss. If silk be used, in twenty minutes the fluid contained only 2·6 per 1,000, with linen 4·3, and with absorbent cotton 4·4.

F. W. Andrewes has pointed out† that while it has been recognised that the *Staphylococcus pyogenes aureus* is one of the most resistant non-sporing organisms both against heat and chemical disinfectants, it has not been generally known that its resistance against mercuric salts is altogether exceptional; but this resistance does not extend to antiseptics of other groups, such as carbolic acid and izal. Bishop Harman confirmed these observations, and stated that he found a similar resistance in the coccus he had isolated from the South African veldt sore.

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* "Revista d'Igiene e Sanita Publica," "Public Health," vol. vii., p. 307.

† "Lancet," January 24, 1903.

Iodide of Mercury.—This salt of mercury is less poisonous than the perchloride, does not coagulate albumen to the same extent, and probably from this reason is a more powerful disinfectant. It is, however, insoluble in water, but with potassium iodide it forms a double salt which is extremely soluble, at the same time retaining its power as a disinfectant. It also corrodes metals, but the mercuric potassium iodide does not affect plated instruments unless used in stronger solution than 1 in 2,000. It is useful as a disinfectant for the hands, as it neither roughens nor irritates the skin. It may be carried conveniently in compressed form.

Chlorinated Lime (*Chloride of Lime*, see pp. 167-169).—Delépine and Ransome recommend* the direct application of a 1 per cent. (1½ ounces to the gallon) solution of chlorinated lime for disinfecting rooms after phthisis. When the solution is not stronger than 1½ ounces to the gallon, its use is attended with practically no discomfort. Coates repeated and confirmed† the conclusions of Delépine, on which are based the method of disinfection practised in Manchester.

The wall-paper in tubercle infected houses is thoroughly saturated with the solution, applied with a soft brush, and is then stripped from the walls. The bare walls, ceiling, and floor are washed over several times with the solution. Klein, Houston, and Gordon did not obtain such good results on wood and cloth with a 1 per cent. solution, but they do not state the amount of the available chlorine which their sample contained. It ought to yield not less than 33 per cent. (see p. 168), but ordinary bleaching powder may contain very much less, and must then be used in correspondingly increased proportion so as to obtain not less than 0·3 per cent. of available chlorine in the solution.

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* "British Medical Journal," vol. i., p 394, 1895.

† British Congress on Tuberculosis, 1901.

Allan and Newman found that linen strips soaked in cultures of plague and of typhoid were sterilized by chloride of lime solution (4 ounces in 3 gallons = 0·35 chlorine) applied as a spray.

Sodium Hypochlorite (*Chloros*).—G. C. Clayton and R. Boyce drew attention* to the disinfecting action of solutions of sodium hypochlorite, and proved that even in weak solutions it had decided disinfecting action on non-spore bearing organisms. Their results were confirmed by Klein,† who also determined that while the above class of microbes will be killed by a 1 per cent. solution in five minutes, spores of anthrax and of *B. enteritidis* required an exposure of one and a half hours. It may be used instead of the solution of chlorinated lime, and may be applied either by brush or spray. Solutions should be kept in tightly-stoppered bottles, and not exposed to the light.

Chloros is a liquid form of sodium hypochlorite, containing 10 per cent. of available chlorine (120 grammes by weight per litre) and having a specific gravity of about 1·15. It is stable in composition, and has the advantage over the ordinary chloride of lime that there is no insoluble matter which might choke pipes and traps if thrown into them. It is completely soluble in fresh or salt water, and does not coagulate albumen. Houston found that chloros (1 : 1,000) killed *B. coli* in one hour on infected linen, and recommends, if this is used, 1 in 250 in ordinary cases, 1 in 100 in exceptional ones.

Potassium Permanganate (see p. 163).—From its readiness to give up oxgyen to organic matter, to sulphuretted hydrogen, etc., the permanganates have a certain field of usefulness, as in street-watering. For this purpose the soda salt is the more economical. The proportion to be used is 1 ℔. of manganate of soda in 1 gallon of water with ½ pint of sulphuric acid.

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* "Journal of the Society of Chemical Industry," vol. xv., No. 5, 1896.

† "Lancet," November 28, 1896.

This amount is to be added to 100 gallons of water. The addition of sulphuric acid, which is inimical to typhoid and organisms present on road surfaces, doubtless contributes to the beneficial action claimed from the use of this solution.

Peroxides.—Reference has been made to the production of hydrogen peroxide (p. 36) in explaining the influence of sunlight in destroying organisms. Altehoefer* found that water may be sterilized by the addition of hydrogen peroxide in the strength of 1 in 1,000 if allowed to act for twenty-four hours. The cholera organism succumbed in five minutes to a 1 in 10,000 solution, and the typhoid bacillus to a 1 in 5,000 solution in twenty-four hours, the solutions being acid, to which fact the result was probably due.

A "10-volume" solution means one that is capable of evolving ten times its own volume of gaseous oxygen when fully decomposed. Solutions of this gas are not very stable, but this may be overcome by the addition of a small quantity of an acid and by dilution.

Organic Peroxides.—C. T. Kingzett's investigations have shown that all essential oils which contain a hydrocarbon represented by the formula $C_{10}H_{16}$, as also all pure terpenes, yield hydrogen peroxide when their oxidized products are treated with water. Thus, when turpentine is exposed to the action of air (or oxygen) it obsorbs oxygen and gives rise to the production of a peculiar organic peroxide (camphoric peroxide, $C_{10}H_{16}O_4$), which remains dissolved in the body of the oil and communicates thereto properties resembling those of hydrogen peroxide. If this oxidized oil be treated with water, or if the oxidation of the oil be conducted in the presence of water, the aqueous solution formed contains hydrogen peroxide and certain substances resembling thymol and camphor. To turpentine so oxidized the term "Sanitas" has been applied, the oil containing camphoric peroxide, while the fluid is a solution of hydrogen peroxide (10 parts per 1,000) with soluble camphor and thymol. One gallon of Sanitas oil should yield 5½ times its own volume or 25 litres of oxygen when brought into contact with water, and is equal in strength to a 10-volume solution of hydrogen peroxide. Eucalyptus oil may be similarly treated.

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* "Centralblatt für Bakteriologie," Bd. viii., No. 5, 1890.

Being non-poisonous and not staining, Sanitas is well adapted for street-watering and for use where organic products require to be oxidized, by spraying or otherwise. At ordinary temperatures Sanitas oil is volatile and gives off the odour of pine-woods. Mixed with sawdust, it is useful for placing in kennels, market-places, post-mortem rooms, and mortuaries. C. G. Moor states that cholera, diphtheria, and typhoid organisms were killed in ten minutes' exposure to a 10 per cent. strength of Sanitas fluid, and similarly to a 5 per cent. strength of the oil (an emulsion containing 45 per cent. of the oil being employed).

The value of these organic peroxides has recently been investigated by F. G. Novy and P. C. Freer,* who confirmed previous observations by Kingzett as to the extremely energetic bodies produced when the organic peroxides are brought in contact with water. Thus they found diacetyl and benzoyl acetyl peroxides to be both chemically and bacteriologically inert until brought into contact with water, when hydrogen peroxide was produced.

Powders.

Fluid disinfectants are frequently combined with some base to form a powder. The disinfectant value of carbolic or cresylic acid combined with lime is very small. The base which is used should not be one which interferes with the action of the disinfectant. A siliceous base is frequently employed, but sawdust and powdered peat are sometimes used, and are useful from their absorptive power. Carbolic powders are apt to lose 1 or 2 per cent. by volatilization, and in any case should be examined to see that they do contain the amount of disinfectant they are stated to hold, as cases have occurred in which it was found that traces only of active disinfectant existed in a sample.

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* Abstract in "Science," No. 375, 1902.

The fine flue-dust from refuse destructors may be utilized in the preparation of a disinfectant powder, izal, creolin, carbolic, or cresylic acid being incorporated with it.

Chlorinated lime or chloride of lime is frequently used as a dry powder (see p. 167).

The Standardization of Disinfectants.

Everyone who has devoted attention to the various kinds of disinfectants, and has studied the experiments made with them, must have sought for some means of comparing the relative efficiency of the agents; but it is too often the case that there appears to be considerable divergence in the results obtained, and it has seemed hopeless to try and reconcile the statements which have been made as to the strengths of solution and the length of exposure necessary to insure disinfection. The best that one has been able to do, as Rosenau puts it (p. 28), has been "to determine the minimum conditions which will furnish trustworthy results and still provide that excess necessary for general practice, or what bridge-builders call 'the coefficient of safety.'"

R. Weil has suggested* that the spores of the *B. mesentericus ruber* should be used for the purpose of testing the influence of various disinfecting agents rather than those of anthrax, on the ground that they are more readily obtainable, and may be maintained for long periods at a known degree of resistance, which could be produced by artificial means. Even when anthrax spores of a known degree of resistance are protected from the light and kept at a constant low temperature, Weil states that they gradually lose their resisting power, and thus become useless for the purpose of continued tests with known strengths of various germicidal substances.

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* "Centralblatt. Bakt. u. Abt.," 30, Nos. 13 and 14, 1901.

J. T. Ainslie Walker* has suggested a way whereby a properly systematized method of estimating the bactericidal value of disinfectants may be established, and S. Rideal supports his project. As absolute figures appear difficult of attainment, Ainslie Walker aims at making results easily comparable. To achieve this, he suggests that some well-known disinfectant be selected as a standard, one known to give regular and consistent results, such as pure phenol.

If the culture be grown in broth, the following procedure may be followed: To 5 c.c. of a particular dilution of the disinfectant in sterilized water add five drops of a twenty-four hours' blood-heat culture of the organism in broth; shake, and take sub-cultures every two and a half minutes up to fifteen. Incubate for at least forty-eight hours at 37° C. If an agar culture be preferred, take up part of the growth on the point of a platinum needle, and distribute it evenly in sterilized water; the resulting emulsion may be used in place of the broth culture, the rest of the procedure in both cases being identical. Modified forms of either of these methods may be employed without affecting the main argument, which, briefly stated, *provides for the strength or efficiency of a disinfectant being expressed in multiples of the volume of carbolic acid performing the same work;* or this multiple may be expressed as the "carbolic acid coefficient."

What is meant may perhaps be understood more clearly from the following examples:

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* "Practitioner," vol. lxix., No. 413, p. 520.

B. Coli Communis—24 *Hours' Broth Culture.*

Disinfectant.	Dilution	Time Culture exposed to Action of Disinfectant (Minutes).						Period of Incubation.	Temperature.
		2½	5	7½	10	12½	15		
"X"	1 : 1,000	+	+	–	–	–	–	48 hours	37°
Carbolic Acid	1 : 100	+	+	–	–	–	–	48 hours	37°

The multiple or coefficient here is ten—*i.e.*, it will require ten volumes of carbolic acid to perform the work done by one volume of "X."

Working with the same disinfectants and the same organism, but using a more vigorous culture, it will be seen from the following table that the same coefficient is obtained:

B. Coli Communis—24 *Hours' Broth Culture.*

Disinfectant.	Dilution.	Time Culture exposed to Action of Disinfectant (Minutes).						Period of Incubation.	Temperature.
		2½	5	7½	10	12½	15		
"X"	1 : 900	+	+	+	–	–	–	48 hours	37°
Carbolic Acid	1 : 90	+	+	+	–	–	–	48 hours	37°

If preferred, the "field" may be extended and divided into intervals of five minutes; but Ainslie Walker contends that no table is complete which does not show a positive result in the first column and a negative result in the last.

Allowing thirty seconds for each medication, and the same time for each subculture, five different disinfectants may be tested against the same culture under conditions which make the results strictly comparable.

Of course, a different multiple will be found when working with different organisms. In the case cited above the multiple found for "X" when tested against a pure culture of *Staphylococcus pyogenes aureus* was 4; but this only bears out Houston's excellent observation* on the necessity for the choice of a disinfectant being governed by the purpose to which it is proposed to put it.

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* "Practitioner," vol. lxix., No. 411.

This test, applied to a number of highly-lauded fluids, promptly demonstrates their comparative inefficiency and costliness. We find that both creolin and izal come out well in the test.

The following table is the result of an examination, on the above lines, of some well-known articles sold for purposes of disinfection, the organism in each case being the *B. typhosus*:

		Carbolic Acid Coefficient.
A.	Fluid	12·2
B.	,,	8·0
C.	,,	2·9
D.	,,	2·6
E.	,,	2·5
F.	,,	1·8
G.	,,	1·4
H.	,,	0·5
I.	,,	0·02
J.	Powder	2·8
K.	,,	0·9
L.	,,	0·4
M.	,,	0·1

DISINFECTION OF ROOMS, ETC., BY THE USE OF FLUID DISINFECTANTS.

R. F. Hutchison,* in a series of experiments, found that cultures of *B. prodigiosus* diluted with water and sprayed into the air of a room were to be found on wall-papers in quantity, especially if these had a rough surface or a raised pattern.

When the air of the room was allowed to remain undisturbed, most of the organisms were found to have settled out within half an hour; but it was observed that slight, unavoidable air currents in the lower strata kept numbers of them in suspension for considerable periods. Other factors which may influence the length of time bacteria may remain in suspension are the amount of moisture present, and the size and specific gravity of the organisms. Provided the air currents are favourable, suspended bacteria may be conducted through very narrow crevices. Thus Petri dishes placed in closed bureau drawers became infected, the organisms having been conveyed through the surrounding chinks.

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* "Zeitschrift für Hygiene und Infectionskrankheiten," vol. xxxv., p. 223.

Experiments were performed to ascertain to what extent bacteria resting upon the floor and in the cracks between the boards thereof are thrown into the upper air by the act of walking, and it was found that those thrown up by the elastic rebound of the boards failed to infect plates suspended at a height of 10 centimetres, while those much nearer were extensively infected. Other experiments proved the passage of bacteria from one room to another through the keyhole and crevices of the closed door leading from one to the other. While the danger of disseminating bacteria by walking over an infected floor was shown to be slight, ordinary sweeping was found to contaminate the atmosphere through its whole extent, even to the ceiling ; hence dry sweeping is to be carefully avoided in the sick-room. The rapid passage of a body from an infected atmosphere in a straight line will draw bacteria through considerable distances In the open air collections of bacteria are inclined to float along in a more or less concentrated mass, even in an apparent calm, and may be carried by very slight currents of air as far as 600 metres.

A somewhat similar series of experiments by F. Kirstein* yielded results closely in agreement with those of Hutchison. Kirstein concludes that the ordinary air currents which occur in dwellings cannot detach living organisms from surfaces upon which they have become deposited and dried, but when bacteria in culture media are sprayed upon fine dust particles, they may, in some instances, be disseminated, since dust is so readily blown about. The longevity of organisms varies enormously, according as they are dried in compact masses or well spread out. The non-spore builders, when thrown into the air in the finest droplets, as when sprayed, retain their vitality for only a comparatively short time, because of the direct influence of light and air, the time varying, of course, according to species. The marked sensitiveness of the tubercle bacillus to the influence of light makes the early destruction of this organism most probable when it is thrown into the air in the form of minute droplets, and thus can be explained the fact that even in consumptive wards, in which there is without doubt a constant discharge of the bacilli into the air, attempts to detect living organisms in the dust, etc., fail, excepting in those cases in which the sputum itself has, through lack of care, become disseminated.

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* "Zeitschrift für Hygiene und Infectionskrankheiten," vol. xxxv., p. 123.

Where walls are washable, or the paper has to be stripped off afterwards, they, as well as the floor and all wood-work, may be thoroughly washed with a disinfectant solution, as izal 1 in 200, carbolic acid 1 in 50, creolin (new) 1 in 300, corrosive sublimate 1 in 1,000, or a 1 per cent. chlorinated lime solution.

Workshops and rooms, especially where there is much dust, might have the floors sprayed daily with one of the above, preferably izal or creolin.

Spraying.

Reference has already been made to this method of disinfecting room surfaces after all textile articles have been removed for submission to steam. It has been in use in Paris for many years, and the results obtained have confirmed the municipal authorities there to continue it. In France a solution of 1 per 1,000 of perchloride of mercury, with the addition of 2 per

1,000 of common salt, or 3 to 5 per 1,000 of tartaric acid, is usually employed. At this strength 1 ounce of the perchloride will make 50 pints of solution, sufficient to cover thoroughly from 3,000 to 5,000 square feet of surface. But there is always the danger of mercurial poisoning resulting in those using it; moreover, the mercury may be deposited* on the gilt of wall-papers, and on metallic articles unprotected by paint, varnish, or lacquer. There are, however, circumstances in which the use of the mercury salt may be preferable, as in cases where there are organisms of high resistance, or where the application of strong solutions of other disinfectants may be difficult to apply. Various other agents have been tried in place of mercury perchloride, but either from exercising bleaching or corrosive effects on wall-paper, or on account of the persistence of the odour of the disinfectant, the number of available agents has been reduced to two—chinosol and formalin.

Chinosol, according to experiments (mentioned below) by Thresh and Sowden, failed to kill *B. diphtheriæ* and other organisms on a white-washed wall when used as a spray in as concentrated a solution as 1 in 150, and they recommend that it should not be used in a less strength than 1 per cent. The objection, moreover, mentioned by Rosenau (p. 151), that spraying is unreliable when the agent used is a non-volatile one, applies to chinosol as much as to mercury perchloride.

Formalin, however, complies with this requirement, and thus acts both in solution and in gaseous form.

The importance of the presence of moisture in order to obtain the full disinfecting power of formaldehyde is explained on pp. 90, 91, but it may be mentioned that Allan and Cribb† found that spraying with formalin solution was more effective than the plan of spraying with plain water followed by the use of a formalin lamp.

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* "Public Health," vol. ix., p. 187, 1896.

† "British Medical Journal," p. 425, August 13, 1898.

S. Rideal* found that a 0·5 per cent. solution of formaldehyde (or 2 ounces of formalin to the gallon) was in excess of the strength required to inhibit the growth of the most commonly occurring organisms. More recently J. C. Thresh and G. Sowden have made a series of experiments to ascertain the disinfectants and the strength of solution necessary to insure sterilization. *B. diphtheriæ*, *B. typhosus*, *B. pyocyaneus*, *V. choleræ*, *M. prodigiosus*, and *Staphylococcus pyogenes albus* were inoculated on wood, on white-wash, and on wall-paper.

The solutions of formalin used were made by diluting a commercial specimen of formalin (*i.e.*, a 40 per cent. solution) to such a degree as to obtain a strength of 0·5 per cent., 1 per cent., and 2 per cent. of pure formaldehyde respectively. The various inoculated surfaces were sprayed in the usual way, and then allowed to stand for three or four hours before making cultivation. The results were throughout more uniformly favourable than with any other solution: 0·5 per cent. solution killed all the above organisms on wood and wall-paper, but failed with *B. pyocyaneus* on white-wash; with 1 per cent. the only failure was also on the same surface; but with 2 per cent. strength every surface was absolutely sterilized. They therefore recommend that solutions containing 2 per cent. of formaldehyde should be used.† They also conclude that for spraying to be efficient every portion of the surface to be disinfected must be thoroughly moistened with the disinfecting solution; merely passing the spray into a room and trusting to its settling upon the surface is utterly unreliable. It will be noticed that Rosenau is doubtful that the entire surface of a room does get wetted, but when a suitable apparatus is properly used there is no difficulty in ensuring this. In practice, with a fine spray properly applied, the surfaces are thoroughly wetted, and yet no damage is caused to the wall covering, whether it be paper, white-wash, or paint, but the wetting must proceed *from below upwards*, and *not* from above downwards.

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* "Public Health," vol. x., p. 61, 1897-98.

† That is, 1 part of formalin to 19 parts of water, or 8 fluid ounces in a gallon.

The absence of experience in the use of the spray in America has led to the instructions on this point in the body of the book (p. 150) being not quite correct. Everyone begins to spray nearest the ceiling, unless he has been told not to do so, with the result that the wall covering, whatever it is, is spoiled by the streams of water running over the dry surface. The correct way is to spray the walls first, *commencing at the bottom and working upwards*, then the ceiling, and finally the furniture and floor. By working from the bottom upwards the whole of the surface can be thoroughly wetted, without even low-class wall-papers being spoilt. This presents no great advantage where it is intended to strip the wall-papers, and under such circumstances the disinfectant fluid may be equally well applied with a garden syringe or a brush. In those cases, however, where it is not intended to strip the wall-papers, complaint, and, possibly, compensation, will be avoided by using a sprayer capable of producing a fine spray at high pressure. It is to be noted that the nozzle should be held quite close to the surface to be disinfected, and the force with which the disinfectant is projected is an essential feature in the efficiency of the disinfection obtained. In cold weather it is desirable to use warm water in making the solution, and to have a fire alight in the rooms to be disinfected (see p. 90 as to temperature necessary).

Thresh and Sowden are quite satisfied " that a proper spray properly used effects room disinfection in the minimum of time and with the minimum of expense, and is more reliable than disinfection by sulphur dioxide or formalin vapour."

Those who have had practical experience of this method for a number of years agree in this decision.

The strength of the liquid used in the spray for ordinary disinfection is made by adding 4 ounces of formalin to a gallon of water, which gives a strength of 1 per cent. of formaldehyde. Mackenzie recommends the addition, to each gallon bottle of the pure formalin (40 per cent. strength) of 5 ounces of glycerine, to prevent the polymerization of the formaldehyde, and therefore it is advisable to use a little more than the amount stated. Five ounces of formalin at this strength should be sufficient to cover 500 to 700 square feet of surface. Five ounces is a convenient amount to use, as the pint or half-pint bottle in which the disinfector carries his formalin may then serve as a measure. The amount of glycerine added prevents the solution drying so quickly when sprayed, thereby retaining the gas longer in solution, which is an advantage ; but it is not sufficient to render the sprayed walls damp for any considerable time. Stronger solutions, up to 10 ounces to the gallon, may be used in special instances, but such strengths may be found unpleasant to the disinfectors. The shortness of the time needed reduces any inconvenience to a minimum. Persons using formalin even in dilute solutions should be careful to keep their hands from getting wet with it.

The advantages of an efficient spraying apparatus may be shortly stated to be : certainty of disinfection, minimum cost, saving of time, both in the operation itself, and also by removing the need for sealing up doors, windows, etc., and of paying a second visit, as must be done when gaseous disinfectants are used. Disturbance of inmates is reduced to a minimum, and if a building be provided to afford a temporary shelter for the inmates of houses undergoing disinfection, the cost of its up-keep may be materially reduced, as there is less occasion for it to be used.

Leslie Mackenzie draws attention to the excellent results obtained by spraying out hospital wards from time to time, and especially those devoted to infectious disease. In scarlet-fever wards he found that such minor complaints as swollen glands, eczematous mouths and noses, small abscesses, and such-like vanished when the formalin spray was used in the wards. He empties a ward, sprays it out, and in a few days re-occupies it.

The *Equifex spray* is similar in appearance to those shown on pp. 150, 151, 152; it has been employed in Paris for many years, and is also well known in Britain. It produces a fine spray at a high pressure, and is adapted for the use of perchloride of mercury as well as for formalin or other disinfectant, as the interior of the apparatus and all parts coming in contact with the disinfectant are lined with ebonite, which is not acted upon by the perchloride solution or by other chemical.

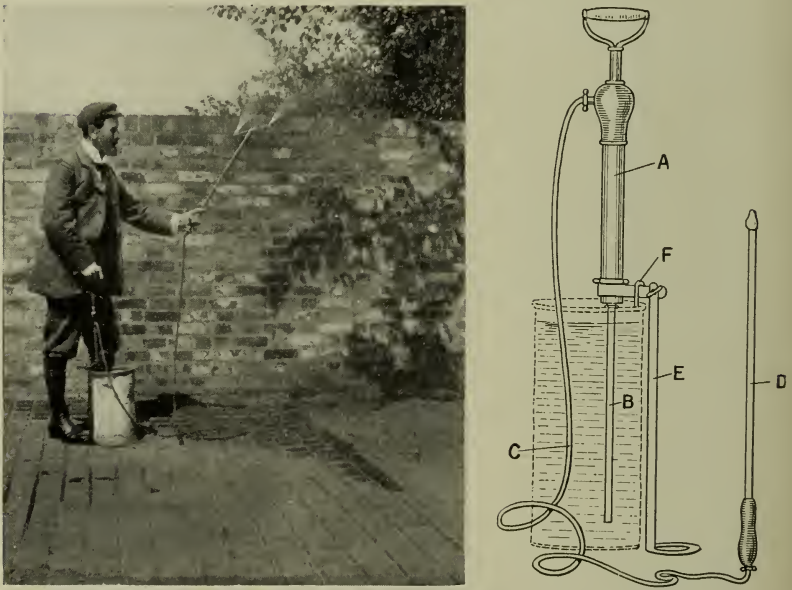

Fig. 22.—The Mackenzie Spray for Ordinary Work.

A, Pump; B, tube (detachable for immersing in vessel containing disinfecting fluid); C, 6-feet rubber tubing; D, brass tube, with wood handle at one end and spraying nozzle at other end; E, pump support, pivoted for folding up. Bucket is shown in dotted lines, and hangs on F.

The *Mackenzie spray* was first devised by Dr. W. Leslie Mackenzie,* who desired an apparatus which might be carried on a bicycle by an inspector or disinfecting officer, might be capable of being worked by one man without inducing such rapid fatigue as might tempt him to scamp his work, and would be inexpensive but reliable. By the adaption of a continuous current garden pump, Dr. Mackenzie devised the apparatus shown in the accompanying illustrations. It has since been rendered more portable by reducing the length of the body of the pump, constructing the largest part of the body of aluminium, and making the apparatus so that it folds up into a very small compass, and weighs only about 4½ lb. The pump has an air-chamber piston rod which thus

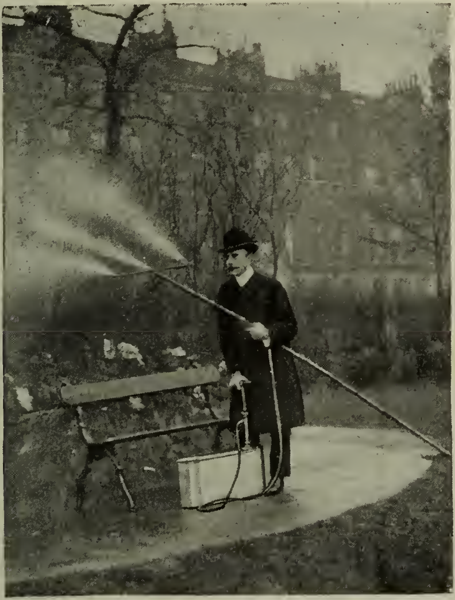

Fig. 23.—THE MACKENZIE SPRAY FOR LARGE AND LOFTY CHAMBERS.

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* "British Medical Journal," p. 898, September 28, 1901.

maintains a continuity of flow, and as the pump inlet is large relatively to the pin-hole outlet of the spray nozzle, the strokes required to keep up the flow are very few. The nozzle ordinarily used gives a fine spray, but if a coarser spray is required another nozzle may be readily substituted, and where wall surfaces are very large, as in hospitals, the labour may be reduced by the use of a cross-piece fitted with a couple of nozzles. With a gentle waving motion a larger area of wall may be covered. The brass tube can be lengthened to 6 feet

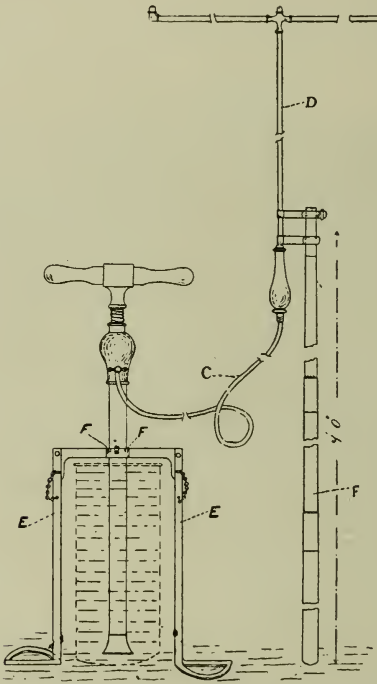

Fig. 23a.—THE MACKENZIE SPRAY FOR LARGE AND LOFTY CHAMBERS.

A, Pump; C, rubber tubing; D, brass tube, with wood handle at one end, and spraying nozzle at other end; E, pump supports, pivoted for folding up; F, extension rods of bamboo. Iron vessel for disinfecting fluid shown in dotted lines.

by screwing on additional tube-rods, so that a lofty room can be sprayed without the use of ladders. A pail to hold the disinfecting solution is usually obtainable in every house, but a collapsible bucket is provided and serves as a convenient method of carrying the apparatus.

To make spraying apparatus work properly, it is necessary that the rubber tubes be clean, unobstructed, and properly fastened ; both the Equifex and the Mackenzie work better with 12 feet of pipe than with 6 feet, but where one man only is available the shorter tubes are more suitable. The leather of the piston should be greased with tallow when necessary, and all the tubes, etc., should be kept clear. When the spraying operation has been completed, or at the end of the day's work, the disinfectant fluid should be drawn off, and the liquid replaced by ordinary water ; the pump should then be worked a few times to wash out the various parts, after which the container should be emptied.

Dr. Robertson's Spray Apparatus.—Dr. William Robertson,* recognising that an apparatus which demanded the employment of both hands to use had certain limitations, has adopted a tank whereby a spray may be maintained for a considerable time.

The principle of the apparatus is as follows : Into a tank fitted with a pressure gauge is forced air until a pressure of 15 ℔. to the square inch is recorded. The same pump is employed, without disconnecting it from the tank, to next force in fluid until the gauge shows a pressure of 45 ℔. After a little over 1½ gallons of disinfecting solution have been forced into the tank, the necessary pressure of 45 ℔. is reached. So soon as this part of the work is finished, the tank may be slung on the back, knapsack fashion, and the pump having been replaced by the flash-tube and nozzle attachment, the disinfecting officer is free to move about at his work. The spray will last for fully twenty minutes without interruption. A stopcock is provided so that the spray may be turned on or off at will.

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* "Public Health," vol. xv., No. 8, p. 477, May, 1903.

At the end of twenty minutes the spray comes to a sudden stop, on account of the operation of a ball valve inside the tank. So long as there is fluid in the tank the valve floats, but with the escape of the last of the fluid the valve drops and seals up the outlet tube in the interior of the tank.

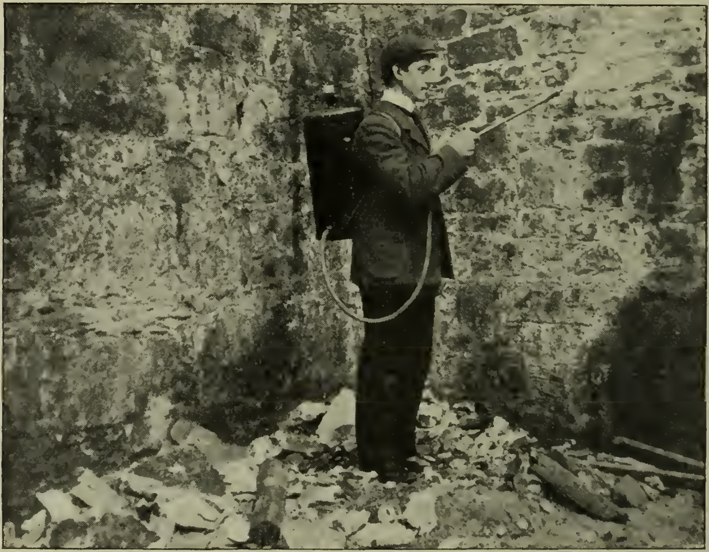

Fig. 24.—Dr. Robertson's Spray Apparatus.

At first the advantage of the valve is not obvious, but when one looks at the gauge it will be seen that it still records 15 lb. pressure.

There is thus a constant amount of air-pressure confined in the tank, and all the disinfecting officer has to do is the forcing in of fluid, which he can do with thirty strokes of the pump. A glance at the illustration will greatly simplify the description. The valve is retained in position by a small cage, inside which the ball floats so long as there is fluid in the tank. To recharge or clean out the tank it must be turned upside down, when one or two strokes of the pump will push aside the valve to permit the escape of the imprisoned air.

The sole objection to the tank is its size, which militates against its being carried about for long distances. But, on the other hand, if it is known how many rooms are to be dealt with, the charged tank can be placed in a van, and taken from house to house without replenishing the original stock of fluid and air. When slung on the back, its weight is so evenly distributed by a curved surface adapting itself to the bends of the body that no inconvenience is felt by the person carrying the apparatus. The nozzle is of a peculiar construction, and, as it can be turned up or down with a touch of the finger, the spray may be directed under beds and into awkward corners.

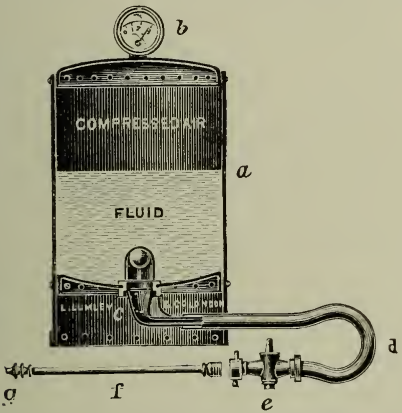

Fig. 25.—Dr. Robertson's Spray Apparatus.

A smaller tank is made, but, while it is lighter, its size only permits the storage of fluid and air sufficient to maintain a spray for ten minutes ; while with the larger tank the pressure is sufficient to spray several rooms. The small size is useful for spraying the interior of ambulance waggons, etc.

Instead of carrying the tank on the back, a specially long rubber tube may be provided, so that the tank can be set in the middle of the floor, and disinfection of surfaces proceeded with. This apparatus achieves a double object : First, it is portable, in the sense that the disinfecting officer can move about freely, and is not required to lift pails or other vessels containing the disinfecting solution ; and, secondly, he has both hands free to guide the nozzle. It is manufactured by L. Lumley and Co., London.

Bed and Body Linen.

Houston writes :* "The question of the disinfection of linen is most important. Within recent years we have come to learn that the urine as well as the fæces may be a fertile means of spreading enteric fever, and soiling of the linen with urine is impossible to avoid. How far, in the case of other diseases, the urine may be infective it is impossible to state. The potentially, if not actually, pathogenic qualities of the perspiration and epidermis must also be borne in mind. Further, handkerchiefs soiled with the discharges of the nose or mouth must of necessity be a source of danger. Moreover, the infection of linen is a factor to be considered day by day during the whole course of an epidemic."

The following agents may be used in the strengths respectively stated :

	In Ordinary Cases.	In Exceptional Cases.
Corrosive sublimate	1 : 1,000	1 : 500
Izal	1 : 200	1 : 100
Carbolic acid	1 : 50	1 : 25
Chloros	1 : 250	1 : 100
Creolin (new)	1 : 300	1 : 150

Steep the linen for one hour in a relatively large bulk of the solution chosen, wring out, and send it to the "wash" in the moist condition. Preference should be given to disinfectants which do not coagulate albumen.

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* "Practitioner," September, 1902.

Boiling such articles as will stand it is in many respects to be preferred to steeping in disinfectant solutions, but unless they are first soaked in cold water stains may become fixed.* The water in which the soaking has taken place requires also to be sterilized by boiling or otherwise. The best plan is to steep the linen for one hour in cold water contained in a cauldron or vessel capable of being heated. Bring the water by heating to the boiling-point, and maintain thus for at least fifteen to twenty minutes, after which, or when sufficiently cool to handle, wring out the linen, and send it to the "wash," without preliminary drying. The addition of some washing soda to the water is an advantage (see also p. 193).

For institutions the *Equifex boiling an* may usefully be employed for disinfecting by boiling.

Books.

(See p. 196.) Barbe has shown† that it is insufficient to expose books simply to such vapours as may be given off from formalin in a vessel at ordinary temperature, but he thought that it was possible to thoroughly disinfect books by the following method : The book was suspended from the cover of an airtight box by a pair of forceps, holding the cover opened backwards, thus allowing the leaves to spread like a fan. He then sprayed into the lower part of the box through a small orifice with an ordinary Richardson atomizer, using 5 grammes of formalin, as the box was about a yard square. As soon as the fluid had all been sprayed into the box, the hole was plugged and the box left undisturbed for twenty-four hours. No infection resulted in guinea-pigs inoculated with tubercle bacilli that had been deposited on the leaves as in previous experiments.

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* Before being subjected to steam disinfection, bedding, etc., soiled with discharges should be moistened with a dilute solution of permanganate, which prevents the stain from being fixed.

† "La Presse Médicale," No. 68, August 23, 1902.

Houston and Newman found that leather-bound books were not damaged during disinfection by use of Lingner's apparatus. It is essential to insure exposure of each page to the gas, as in the method suggested by Barbe. Books are, however, difficult to sterilize, and unless they can be done properly it is better to destroy all except those of special value. Fresh air and sunshine are stated by Shelly to be the best disinfectants for books used by measles patients.

Disinfection of Excreta.

A. C. Houston* has made some reliable experiments on the disinfection of excreta. The results indicate that corrosive sublimate 1 in 500, izal 1 in 100, copper sulphate 1 in 20, and carbolic acid 1 in 20, are all efficient, the duration of contact being one hour, and the fæces being mixed as thoroughly as possible with the disinfectant solution. Bleaching powder (5 per cent.) in one experiment did not destroy all the spores of bacteria, but in another experiment a 1 per cent. solution was effective, both as regards spores and bacilli. Formalin, lysol, and cresol were also found of value. The following are the relative strengths which should be used :

1. Add to the stool 1 to 2 pints, according to its bulk, of one of the following solutions: Corrosive sublimate, 1 in 500 (L.G.B. formula); creolin, 1 in 150; izal, 1 in 100; carbolic acid, 1 in 40; lysol, 1 in 40; cresol, 1 in 40; copper sulphate, 1 in 20; formalin, 1 in 20; bleaching powder, 1 in 50 (1 pint, followed after half an hour by 1 pint dilute sulphuric acid, 1 in 50). Mix as thoroughly as possible, and allow to stand at least one hour. A piece of firewood, which should be burnt immediately after use, will be found useful for

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* "Practitioner," September, 1902.

mixing. Vincent* recommended as the cheapest reliable disinfectants for this purpose (1) chloride of lime, with 1 per cent. of hydrochloric acid ; (2) copper sulphate, with 1 per cent. sulphuric acid ; (3) cresol. Alkaline carbolic preparations are not recommended in typhoid and cholera cases.

2. *Boiling.*—Add about two teaspoonfuls of the crystals of potassium permanganate to 2 pints of water in an enamelled vessel, bring to the boil, and pour the contents over the stool.

Mixing is to be recommended, but it is not so necessary as in method 1.

Allow to stand for half an hour.

Both as regards urine and fæces, a fair allowance is 4 parts of *boiling* water to 1 part of the substance to be disinfected. In the case of the urine, the permanganate may be dispensed with altogether, or a small amount used.

Where infected excreta cannot be thrown down drains after disinfection, lime may be used as described (see pp. 203-204), and the fæces subsequently buried, or they may be mixed with peat or sawdust, or received in pails containing such with a disinfectant, and the whole subsequently burned. Porcelain receiving pails, with tightly-fitting lids, may be used, the contents being removed daily for destruction by boiling or burning.

The simplest form of disinfector for excreta, applicable equally to sputa, is the disinfector of Major Cummins, which was used with success in the South African campaign. It consists of a pan into which the infected material is put, the utensil which contained it being dropped into the same or into an adjoining pan. These pans are fitted over a hearth, and the whole is covered up with a hood, through the back of which the chimney rises. The front part of the hearth below the hood is perforated, so that a stream of air passes continuously over the surface of the pans. Carbolic acid or permanganate is added to the excreta, and it is found in practice that no nuisance is created by the operation of the apparatus.

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* "Ann. de l'Inst. Pasteur," January, 1895 ; "Public Health," vol. vii., p. 226.

The Newcastle Sterilizer for Infected Excreta.—At the Birmingham Congress of the Sanitary Institute in 1899 Dr. Henry E. Armstrong, Newcastle-upon-Tyne, exhibited a model of an apparatus for the disinfection by steam of the

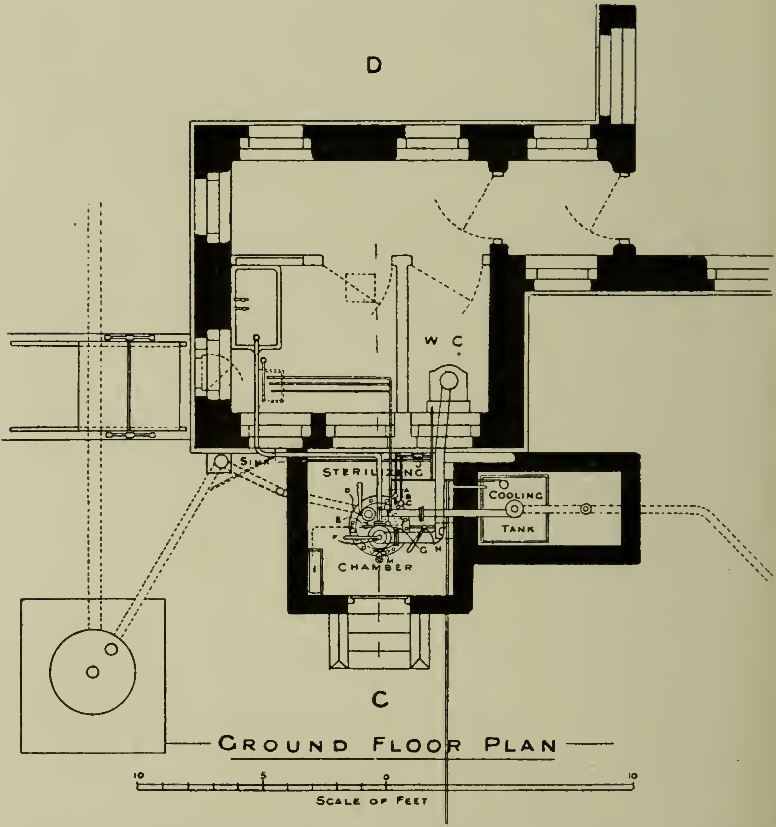

Fig. 26.—The Newcastle Improved Sterilizing Apparatus for the Treatment of Excreta.

excreta in cholera and enteric fever, devised by Mr. W. G. Laws, City Engineer of Newcastle, and himself. The appliance was then in use in the Cholera Hospital and Enteric Fever Pavilion at Newcastle. From that date to the present time the sterilizer has given satisfaction. But experience in working showed certain minor defects, which are now remedied.

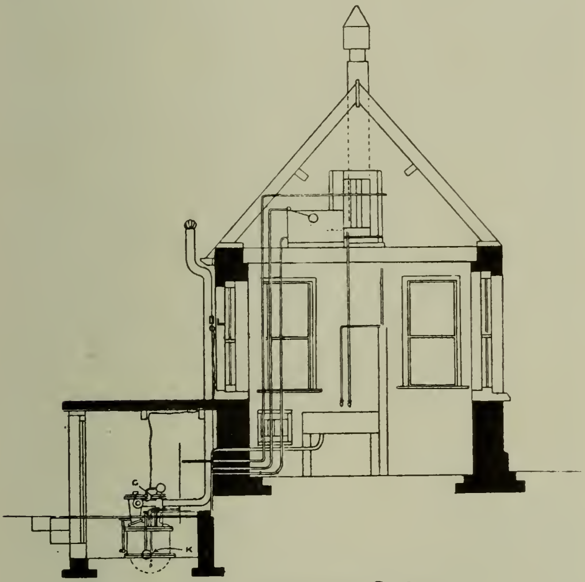

Fig. 26a.—THE NEWCASTLE IMPROVED STERILIZING APPARATUS FOR THE TREATMENT OF EXCRETA.

The receptacle of each sterilizer, in its improved form, receives the discharges from a water-closet and a slop-sink. The escape of steam through these pipes into the closet, etc., is prevented by suitable valves. The disinfection of soil-pipes, wastes, and ventilating shaft is provided for. The disinfected excreta, etc., fall into a tank two-thirds full of clean cold water, and are cooled before being syphoned off into the drain. The process of disinfection is short, sharp, effective, and free from nuisance.

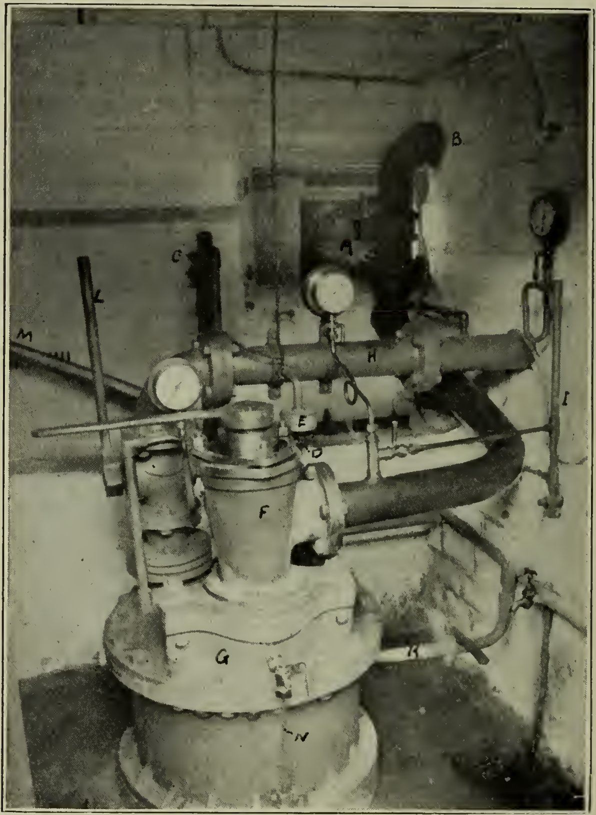

Fig. 27.—Arrangement for Sterilizing Soil and Vent Pipes.

A, Hinged valve to soil-pipe below w.-c. basin, operated by handle of closet, B, soil-pipe ventilator carried above roof, and having weighted hinged valve on outlet, operated by chain ; C, I, steampipes ; D, E, float and electric bell connection ; F, three-way cock ; G, sterilizing pan ; H, discharge-pipe to cooling-tank ; K, overflow to cooling-tank ; L, handle of discharge-valve ; M, slop-sink waste discharging into sterilizer ; N, water gauge.

Each sterilizer consists of a pan of 30 gallons capacity, placed in an annexe to the offshoot for the ward conveniences.

Leading into it are the waste-pipes from the water-closet and slop-sink, their outlets into the pan being governed by a three-way cock, which also controls the outlet pipe from the sterilizer. Steam is conveyed into the pan by two separate pipes, one of which (sterilizing) reaches to the bottom, the other (ejecting) ends inside the cover of the pan. These pipes and a third (water wash-out) are each governed by a separate valve. The depth of the liquid in the sterilizer is indicated by a water gauge.

The *modus operandi* is as follows :

When the pan is about two-thirds full, an electric bell, operated by a float on the surface of the liquid contents, rings to call the attendant, who closes all the valves. The sterilizing cock is then turned on, and steam entering at the bottom rapidly raises the temperature to about 250° F., as shown by the pressure gauge standing at 30 ℔. After maintaining this temperature for fifteen minutes, which is ample for the sterilization of the liquid, the sterilizing steam-cock is closed, and the steam-ejecting cock is opened. Shortly afterwards the outlet valve is opened, when the whole of the liquid is at once discharged into the cooling-tank, and the pan is washed out.

The disinfection of the soil and vent pipes is provided for by a separate valve near the outlet of each, so as to allow access of the steam through their entire length.

The temperatures in the pan and pipes are indicated by three pressure gauges.

In case of the pan accidentally becoming more than two-thirds full, after sterilization the surplus is drawn off and discharged into the cooling-tank by a special pipe, so as to make space in the upper part of the pan for the accumulation of steam sufficient to eject the contents after disinfection.

The cooling-tank, which has a capacity of 120 gallons, is provided with water-supply to cool the sterilized liquid, etc., and has an automatic flush.

The whole operation occupies from fifteen to twenty minutes, so that a charge can be boiled and cleared out every half-hour, thus allowing the sterilization of from 200 to 250 gallons daily from each ward, an ample provision for twenty patients. By this method the evacuations are rendered harmless before leaving the pavilion, and no unsterilized matter is left in any of the pipes.

Urine (see pp. 232, 255).—Infection in typhoid fever may remain in the urine for many weeks. It may be removed by the administration of urotropin (7 to 15 grains three times a-day). This is usually well borne, but a few cases of hæmaturia following its use have been reported. For disinfection of urine outside the body the agents mentioned on p. *72* may be used. The presence of a large quantity of albumen does not appear to interfere with their disinfectant power if the urine is acid.*

Rags in Bales.

In view of the statement that no disinfectant can penetrate such a firm mass as a compressed bale of rags (p. 218), it may be well to quote some experiments made by Dr. H. Franklin Parsons on behalf of the Local Government Board in 1893, for particulars of which I am indebted to Dr. Parsons. They were made in a Washington-Lyons apparatus at the Strand Disinfecting Station.

1. A sack of rags, compressed by hand, weight 190 ℔., with a self-registering thermometer in the centre, was placed in the apparatus, and exposed to steam at 20 ℔. pressure for fifteen minutes, air being previously exhausted. After exhausting steam and exposure to hot air the bale was withdrawn, and the central temperature found to be 217° F.

2. A hydraulically compressed iron-bound bale weighing 6¾ cwt., measuring 4 feet 3 inches long, 3 feet 6 inches wide,

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* "Philadelphia Medical Journal," January 12, 1901.

and 2 feet 1 inch deep, had two thermometers placed in it, one in the centre, the other with the bulb 18 inches from the end of the bale, 14 inches from the side, and 12 inches from the surface. The bale was then placed in the apparatus at 6.50 p.m., and exhaust turned on; at 7.5 exhaust turned off, and steam turned on; at 7.22 a pressure of 20 ℔. was registered; at 7.40 exhaust was turned on for twenty minutes, when steam was again admitted for thirty minutes; and at 9 the bale was taken out. The centre thermometer was broken, but was standing at 270° F.; the second registered 264° F. The bale appeared perfectly dry.

Similar experiments were made in a Goddard-Massey and Warner's Nottingham steam disinfector by Dr. Boobbyer, Medical Officer of Health for the Borough of Nottingham. Two compressed bales (a Belgian and a German) similar to the second above-mentioned were tested. In one instance the temperature in the centre of the bale was 245° F., in the other 255° F. The process took two hours in the case of the first bale, and two and a half hours in the second.

Cattle Markets, Pens, Trucks, Fish and Milk Vans, Stables, Quays, etc.

In cases where absolute disinfection is required in the presence of considerable dirt the Equifex hot-spray disinfector is the most efficient appliance available, although its bulk makes it unsuitable for domestic purposes. It consists essentially of a high-pressure boiler, of which the steam communicates with the top of a chamber containing disinfectant, which leads into a mixing vessel, and the boiler water, under the same pressure, communicates likewise with the mixing vessel. The sizes of the orifices by which the disinfectant chamber and boiler respectively communicate with the mixing vessel determine accurately the percentage composition of the disinfectant liquid, which is led through one or more long tubes to sprayers, each of which delivers a spray 12 to 18 inches wide. The temperature of the spray is as high as 110° C., and the force at which it is delivered is sufficient to dislodge any incrusted accumulation of dirt, such as occurs in cattle-markets, on fish-trucks, and the like. The apparatus is mounted on a light four-wheeled truck, which may be moved about readily by two men. The coal consumed is about 8 ℔. per hour per tube working. This method has been in use for a number of years in the Paris cattle-markets. Every cart which has brought animals into the market receives a douching before leaving the premises with either a hot or cold disinfectant solution, according to the circumstances of the case. The hot-spray apparatus has been used with success for the cure of persistent mould infections, which it had been found impracticable to remove in any other way ("Transactions of the Jenner Institute,"

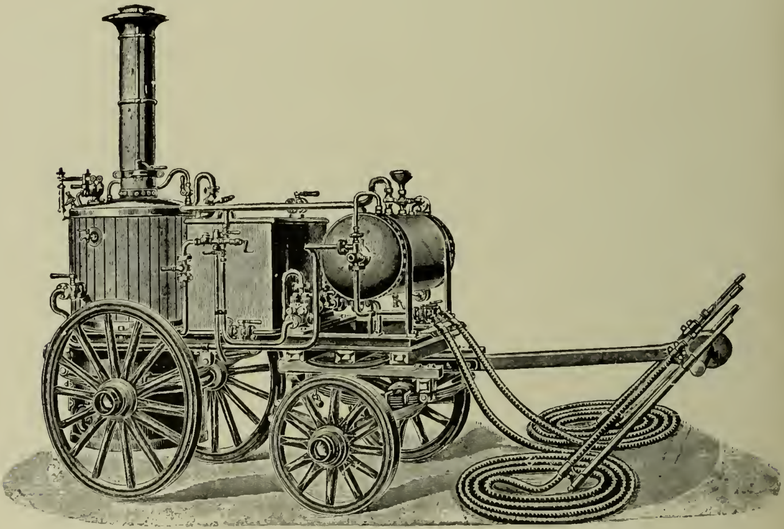

Fig. 28.—THE EQUIFEX HOT-SPRAY DISINFECTOR.

1899). An alternative form of this apparatus is made for the use of ships.

For applying Disinfectants to Yards, Market-places, Drains, etc.

Where it is desired to apply a disinfectant to a large surface, which must in the first instance be clean, and there is no reason to expect so persistent or hard an incrustation as to demand the application of the hot spray, the Equifex disinfectant cleanser or the Chloros Distributor may be employed.

The Equifex disinfectant cleanser consists of a cylinder containing a weighted piston, below which is a liquid disinfectant, and above is a connection on the one side to a hose which may be coupled to a hydrant, and on the other side to a mixing-vessel, connected with the outlet-hose and spray. The disinfectant also is connected to the mixing-vessel. In use the apparatus is connected to the nearest hydrant, or to a pump where no hydrant is available, and water is passed through without any disinfectant until the superficial dirt has been removed. When it is desired to disinfect, the turning of a cock opens communication between the disinfectant and the mixing-vessel, and the stream of water is changed into a stream of disinfectant of a percentage composition exactly determined by the size of the orifices through which the water and disinfectant respectively reach the mixing-vessel.

The Chloros Distributor.—Its invention was due to the action taken by the Glasgow municipal authorities to purify thoroughly the infected districts during the visitation of the bubonic plague, and the accompanying illustration shows it in practical use in a courtyard of that city.

The method of working the apparatus is simplicity itself. The area is first thoroughly well flushed with plain water through hose from the street mains, the distributor first being inserted between two lengths of hose and connected by

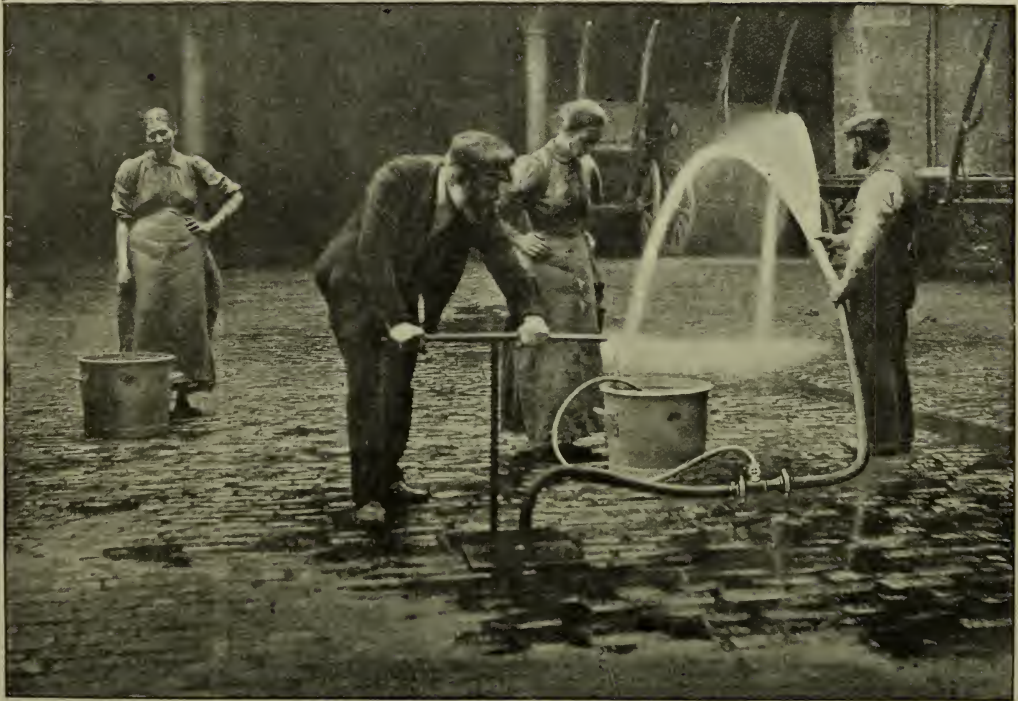

Fig. 29.—The Chloros Distributor in use in a Glasgow Court during the Recent Epidemic of Bubonic Plague.

means of a short piece of rubber pipe to the concentrated supply of disinfectant; the valve is then opened, allowing the disinfectant to be drawn into and thoroughly mixed with the water as it passes through the distributor for the final flushing. The flushing is continued until the desired quantity of disfectant is distributed.

The distributor is constructed entirely of hard gun-metal, and is of extremely substantial construction to withstand the roughest usage.

It is connected to hose from the street mains at A, and to the disinfectant supply at B. The water, under pressure from the mains by its increased velocity through the constricted passage C, draws the disinfectant through the pipe B and the valves D and E, and thoroughly mixes it whilst so doing. The mixture is distributed through a suitable spreader attached to a hose connected to the outlet F. The supply of disinfectant can be regulated to any desired proportion by the adjustment of the needle-valve E, or can be shut off altogether at the valve D.

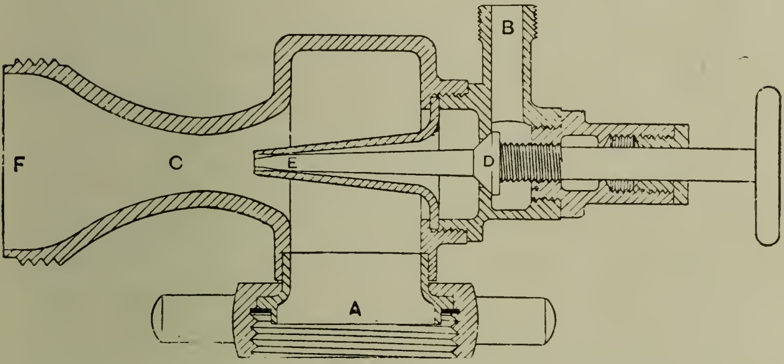

Fig. 30.—SECTION OF CHLOROS DISTRIBUTOR.

The advantage of apparatus like the above is that it permits a disinfection to be performed without any waste of disinfectant, and with a control over the proportion of disinfectant used which is not attainable by other means. This method is useful in the cleansing of cattle, meat, fish, and fruit markets, courts and alleys, stables, cab-ranks, etc.

Disinfection of Ships.—This is fully described on pp. 233-242. To carry out the methods there mentioned, two apparatus may be described, viz., the Clayton apparatus and the Newcastle disinfecting hulk.

The Clayton method consists in driving the gas produced by the combustion of sulphur in a special apparatus (moored on a barge alongside the ship) into the lower part of the hold of the ship, which has been made as nearly airtight as possible. The air in the upper part is gradually extracted, and passed over the heated sulphur in the furnace, and thus the interior of the ship becomes permeated with sulphur dioxide to the extent of about 10 per cent. Calmette and Hautefeuille, of the Pasteur Institute at Lille, have experimented with the Clayton apparatus, and report* favourably thereon. They recommend that where it is employed it should be scientifically controlled in the following particulars: (1) All internal hatches should be opened in ships, only the external hatches being closed; (2) control tests should always be made; (3) rats should be used in such controls as well as bacterial cultures; if rats are unobtainable cockroaches will suffice; (4) a report stating the exact exposure and percentage of gas used and full particulars as to tests should be signed by the captain of the ship and the medical officer in charge.

From experiments made by F. B. Guthrie,† it appears desirable not to use sulphur when there is flour or grain in the cargo, as the action of the sulphur fumes affects one of the constituents of the gluten—namely, the glutenin—causing it to become soft and sticky. Grain bleached with sulphur fumes is unfit for milling.

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* "Revue d'Hygiene," tome xxiv., No. 10, October, 1902.

† "Agricultural Gazette," New South Wales, vol. ii., No. 7, 1900, and vol. xii., No. 6, 1901.

*The Newcastle Disinfecting Hulk** is made by Messrs. Goddard, Massey, and Warner, Nottingham, and consists of :

1. *Two Tanks for Solution of Perchloride of Mercury*, with appliances for pumping and spraying the drench.
2. *A Steam Disinfecting Apparatus* for clothing, etc.
3. *A Store of Liquefied Sulphurous Acid* for disinfecting cabins, berths, holds, etc.

'The hulk measures 54½ feet extreme length, and 18½ feet extreme breadth. The available space for machinery and storage is 29¼ feet long by 18 feet wide, forming the hold. The deck is continuous along the sides about 2 feet wide, and at the fore and aft about 12 feet by 12 feet. There are two barrels for solution of perchloride of mercury, together having a capacity of about 600 gallons, and a metal tank of a capacity of 190 gallons ; a steam disinfector 3 feet diameter by 5 feet 6 inches long ; a steam pressure gauge to register the temperature and pressure. The air-compressor is of the vertical type, and has steam cylinders 4 inches diameter by 3-inch stroke, with air-compressing cylinder 5 inches diameter by 3-inch stroke. It is provided with fly-wheel and crank shaft to give even speed and regulate length of stroke ; the air inlet and outlet valves are gun-metal. The compressed air is conveyed to an air-receiver 2 feet diameter by 5 feet high, made of steel boiler-plates to form a reservoir of air at a pressure. The steam boiler is vertical type of four horse-power, 6 feet high by 3 feet diameter, having internal fire-box and two cross-tubes ; it is provided with steam-pipes, and connected with the air-compressor on one side and the steam disinfector on the other. The boiler is capable of working at a pressure of 60 pounds on the square inch, but a less pressure is found sufficient to work the air-compressor and the disinfector. When working, steam is got up in the boiler, and then passed by opening a valve into the pipes, so that clothing may be disinfected as desired by steam; but in order to use the perchloride of mercury spray the air-compressor is started and allowed to compress air to about 10 ℔. pressure inside the air-receiver. The compressed air supply pipes connect between the air-receiver and two special spray nozzles, and they are also connected to the bottom of the perchloride storage tanks. When the spray is used, the compressed air passes down a double pipe, conveying it along with the solution, and they meet together at the nozzle, where the force of air forms a spray at a pressure sufficient to carry several feet, and thus the decks and internal parts of an infected vessel may be easily covered with a fine spray of solution of perchloride of mercury.'

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* From Report of H. E. Armstrong, Medical Officer of Health to the Tyne Port Sanitary Authority for the year 1894.

The Equifex hot-spray apparatus is adapted for use on ships, working off the steam of the donkey or main boilers.

Tuberculosis.

Rooms.—The methods of disinfection in use in Manchester are thus described by Dr. Niven:

A solution of chlorinated lime of the strength of 1½ oz. to the gallon is used.

The wall-paper is thoroughly saturated with this solution, applied with a soft brush, and is then stripped from the walls.

The bare walls, the ceiling, and floor are washed over several times with the solution, and any articles of furniture which will admit of such treatment are similarly washed over.

Articles of clothing, bedding, etc., are taken away to be disinfected in the steam disinfector, and a formic aldehyde chamber is used for boots, books, etc. In houses which are in a clean condition, and where it is certain that there has been no direct soiling of the walls or floors with sputum, and where the infectious dust, if present, has come from soiled pocket-handkerchiefs or articles of clothing, the chlorinated lime method of disinfection is not considered necessary, and the

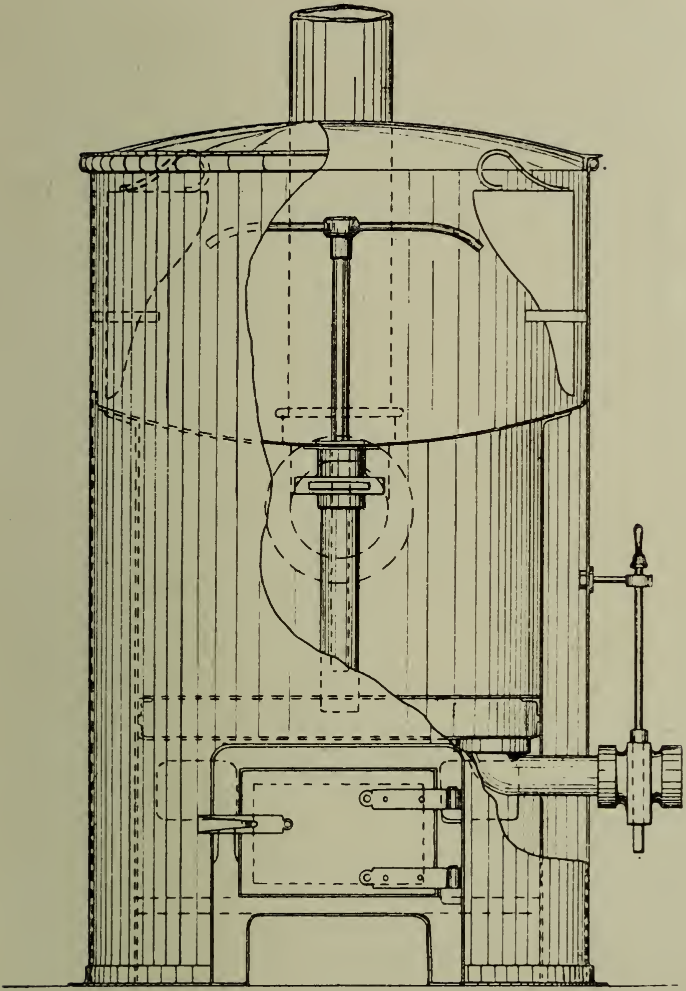

Fig. 31.—EQUIFEX ROTARY STERILIZER FOR SPUTA, EXCRETA, ETC.

method of disinfection recommended by Esmarch is practised.* The wall-paper is rubbed well with dough kneaded to a proper consistency, the fragments being carefully collected and burned.

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* "Zeitschrift für Hygiene," Bd. 2, heft 3.

Floors, painted walls, and woodwork are washed with soft-soap and water, and ceilings are lime-washed. These operations are generally left to the tenant.

In addition, bedding, articles of clothing, etc., are either disinfected by steam or washed with boiling water.

Dr. Harold Coates has pointed out* that a certain amount of care must be taken to make sure that all dust is removed from the walls, especially from the angles and corners, and to properly rub down a fair-sized room takes a considerable time, and that this method of disinfection is useless in cases where the paper is directly soiled with sputum. Owing to the mucus which it contains, the dried sputum sticks tenaciously to the paper, in spite of repeated rubbing with dough. This method of rubbing the walls with dough is an excellent way of periodically cleaning a room so as to keep it free from dust.

If the house is dirty, or if the patient has not taken personal precautions, or if marks of sputum are observable on the floor or walls, the Corporation disinfect the surfaces with chlorinated lime solution in the manner described above.

Dr. Hermann M. Biggs† states that the treatment of apartments usually recommended in New York is that kalsomined or whitewashed walls and ceilings are washed with a solution of washing-soda (½ pound to 3 gallons of hot water), and then kalsomined or whitewashed again ; papered walls and ceilings are similarly washed and repapered ; the woodwork is scrubbed with the soda solution and repainted. Renovation rather than disinfection is called for. Bedding, carpets, etc., are disinfected by steam.

Sputum.—The nummular masses are extremely difficult to disinfect in any way short of burning (see pp. 227, 287). Major

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* British Congress on Tuberculosis, 1901.

† "Journal of the American Medical Association," December 27, 1902.

Cummins' apparatus is suitable for this purpose (see p. *68*). In many sanatoria the sputum is first mixed with sawdust or powdered peat.

Boiling is the next best method, especially in water or disinfectant containing an alkali, which tends to break up the masses, or, at least, to prevent coagulation, and raises the boiling-point. Boiling should be continued for at least half an hour, as experiments have shown that organisms enclosed in sputum may be particularly resistant. The boiling may be carried out in the autoclave shown on p. 228, the pans or spittoons being put directly into it. An alternative form, adapted for use in cases where a large number of utensils require to be disinfected rapidly, is the Equifex revolving apparatus. In this, when a slight pressure of steam is formed, the water, or, better, soda and water, in the boiler is lifted through the central tube, and escapes through a number of radial arms which are supported on the top of the central tube. These arms operate in the manner of a Barker's mill, and revolve at a great speed, projecting the boiling disinfectant over the whole circumference of the upper pan, the jets being so arranged as, between them, to cover it entirely. Should the pressure rise beyond that at which the apparatus is intended to work, the cap in which the radial arms are fitted is lifted, and the steam is thereupon free to escape through holes in the central pipe which the cap normally covers. On the operation being finished a cock is opened, permitting the escape of steam from the boiler, and the liquid thereupon forced through the other tube which leads to the underside of a perforated grid, placed in the boiler below the opening of the central tube. In this way any solids which may have been in the pan are borne down below the grid, and prevented from obstructing the tube through which the disinfectant solution escapes into the upper pan.

Arthur Latham* has collected information as to the disposal of tubercular sputum at a number of sanatoria. In the majority some form of pocket-flask is used alone or conjointly with spit-cups in bedrooms, and the use of scraps of linen or Japanese handkerchiefs ; water, lysol (alone, or 1 per cent. with soft-soap 5 per cent.), carbolic acid (5 to 20 per cent.), are principally used. On the Continent of Europe a solution of cresol and soft-soap is much used both for spittoons and for soaking soiled linen. The "cresol savonneux" is prepared by gently heating equal parts of crude or purified cresol with soft-soap ; 500 grammes of this is added to 10 litres of water for use.

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* "The King's Sanatorium Prize Essay."—"Lancet," January 3, 1903.

In thirty-six sanatoria the sputum is burnt, generally without other treatment, but in a few cases sawdust, peat, or ferrous sulphate is added. Boiling is practised in two with soda, in one by passing waste steam into a tank ; in twenty-two the sputum is poured into w.c. or sinks, being boiled previously in a few instances.

Tuberculous Milk may be purified from tubercular infection by use of the Pakes and Barnes apparatus. This consists of coils, one part of which is heated by steam, and the other cooled by circulating water, brine, or other convenient refrigerant ; and the apparatus is so arranged that after each or any sterilization the tubes can be entirely cleaned by steam, soda, and water, or other suitable means. In this way the process of sterilizing the milk from those organisms which perish below about 100° C. is performed continuously, with the reduction of the milk to about atmospheric temperature, and in practice this has been found to produce milk which, neither chemically nor by taste, is to be distinguished from the untreated fluid. This apparatus is also adequate for the removal of typhoid, diphtheria, and cholera organisms, though possibly (like all apparatus short of pressure sterilizers, which alter the nutritive quality of the milk) not for diarrhœic organisms (Flügge, Klein's enteritidis).

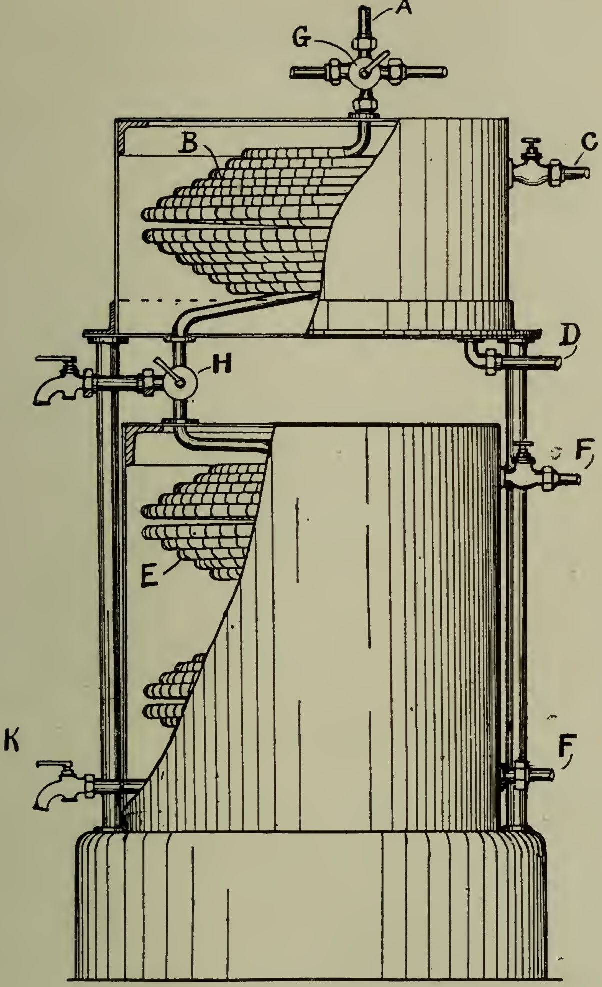

Fig. 32.—PAKES AND BARNES' MILK STERILIZER.

A, Milk inlet; B, heating coil; C, steam inlet; D, drain; E, cooling coil; F,F, cooling water circulation; G, fourway cock for milk and for steam or water clearing; H, threeway cock for hot sterilized milk, to draw off or to cool.

Tests of the Efficiency of Sulphurous Acid and Formaldehyde as Disinfectants.

M. Calmette proposes* to measure the penetrating power of sulphur dioxide by the use of glass tubes closed at one end and filled with dry fine sand coloured blue with litmus. These tubes are graduated, and the open end closed with cotton-wool. The tubes are to be placed horizontally at different heights in the room to be disinfected. The gas penetrates more deeply the greater its concentration, or the longer the time of exposure, and the sand traversed becomes red. A table can be drawn up indicating the penetration necessary.

For testing formaldehyde M. Calmette mixes a quantity of hydro-alcoholic solution of fuchsin rubine with liquid serum of the horse, and dries this at a temperature of 40° C. This dried serum in bright red scales dissolves very readily in water, but after exposure to formaldehyde the colour becomes fixed and insoluble in water. Tubes containing dry sand or cotton-wool having some of these scales at intervals may then be placed in the rooms to be disinfected.

Bacteriological tests may also be made by placing cultures in little glass cylinders and exposing them in the rooms.

Preparation of Solutions.

In making solutions of disinfectants of the strengths mentioned, it may be useful to take 5 pints, or multiples thereof, as a standard to work upon, as 5 pints contain 100 fluid oz.; and therefore to make a 1 per cent. solution it is necessary to take 1 oz. of disinfectant, and fill up with water to 5 pints, and so on for other strengths.

In dealing with formalin, it is usual to mention the strength of formaldehyde required, and as formalin contains 40 per cent., it is necessary to add 1 part of formalin to 19 of water to make a 2 per cent. solution; 1 part to 9 to make a 4 per cent. solution; 1 part to 39 to make a 1 per cent. solution.

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* "British Medical Journal," May 23, 1903.

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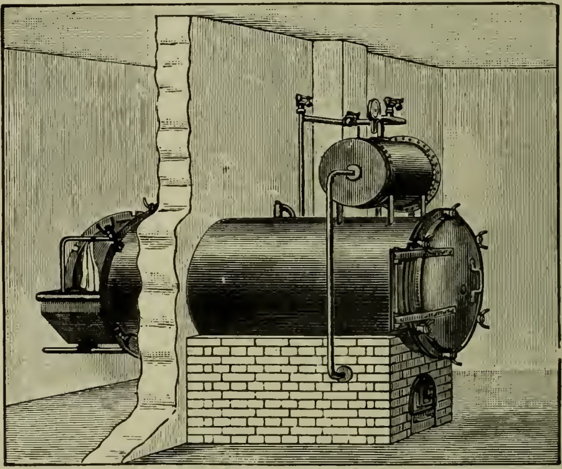

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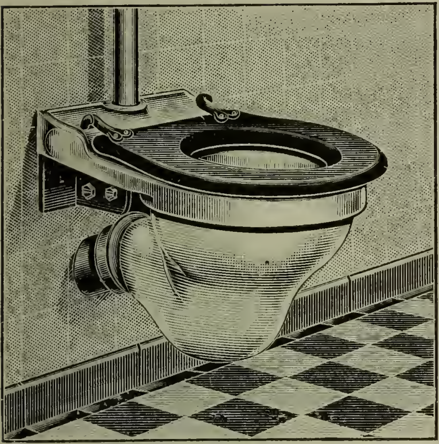

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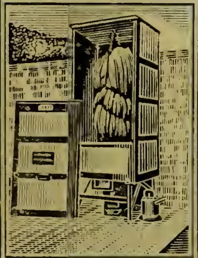

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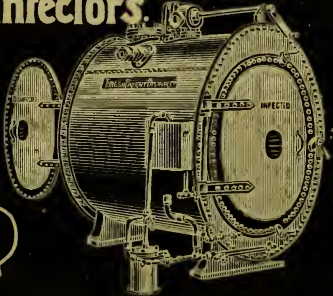

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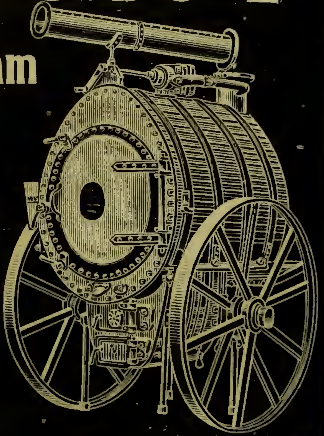

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